Final Report of Analytical Results of

THE 106-MILE DEEPWATER SLUDGE DUMPSITE SURVEY - SUMMER 1986

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Prepared by

Wayne Trulli, William Steinhauer, Carlton Hunt,
Paul Boehm, and Christine Werme

BATTELLE
Ocean Sciences Department
397 Washington Street
Duxbury, MA 02332

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

TABLE OF CONTENTS
(Continued)

LIST OF APPENDICES

Page

APPENDIX A

TABLE 1. PARAMETERS ANALYZED IN BASELINE WATER SAMPLES FOR THE 106-MILE SITE MONITORING PROGRAM

Water Samples

1. Trace metals: Silver (Ag), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Lead (Pb), Zinc (Zn)

2. Priority pollutant Polycyclic Aromatic Hydrocarbons (PAH): acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)-fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene

3. Priority pollutant organochlorine compounds: aldrin, α-benzene hexachloride (BHC), β-BHC, γ-BHC, δ-BHC, chlordane, 4,4' dichloro-diphenyltrichloroethane (4,4'-DDT), 4,4' dichlorodiphenylethane (4,4'-DDE), 4,4' dichlorodiphenyldichloroethane (4,4'-DDD), dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxaphene, polychlorinated biphenyls (PCB) (total)

4. Other organics: Bis (2-ethylhexyl) phthalate (BEPH), coprostanol

5. *Clostridium perfringens*

6. Water quality parameters: Total suspended solids (TSS), chlorophyll *a*, adenosine triphosphate (ATP), dissolved oxygen, pH, salinity, turbidity, and temperature

conditions to determine whether ocean dumping of sludge is adversely impacting the marine environment.

To initiate preliminary studies on sludge transport in the nearfield and to collect baseline data at selected stations, EPA conducted a survey at the 106-Mile Site during the summer of 1986. The survey was conducted aboard the EPA Ocean Survey Vessel (OSV) Peter W. Anderson. At that time, disposal rates for sewage sludge were approximately 30 percent of the anticipated annual disposal rate (Battelle, 1986a). Although the dumping rate during the survey was low relative to the projected 1988 rate (100 percent), sludge components could be distributed over a wide area. As a result, the station locations were selected in areas thought to be free of contamination from sludge disposal. Sludge dumping activities at the site and the strategic location of the reference stations permitted the collection of plume transport data and baseline data from the water mass at and near the site (Battelle, 1986b,c).

The survey was divided into two legs. Leg I was conducted from 21 to 28 August 1986, and Leg II was conducted from 14 to 20 September 1986. Activities during Leg I of the survey were designed to track an actual sewage sludge plume and to provide water column data for specific sludge tracers to determine if sewage sludge was transported in detectable concentrations to the dumpsite boundary. In addition, Leg I activities were designed to provide baseline water column data for a variety of parameters at selected stations within the vicinity of the site. The activities conducted during Leg II were designed to deploy current meters which would provide six-month data on oceanographic currents in the vicinity of the 106-Mile Site. These data will be presented in a separate report.

1.2 SURVEY OBJECTIVES

The August/September 1986 survey at the 106-Mile Site focused on preliminary implementation of the overall 106-Mile Site monitoring plan (Battelle, 1987a). Although the plan was still under development during the survey, studies during the survey were designed for two purposes: 1) to collect baseline data, and 2) to make preliminary observations on the transport of sludge plumes, which could be used as guidance for developing a nearfield monitoring strategy for tracking plumes. All major objectives, summarized below, were completed during the two legs of the survey.

1. To conduct a preliminary study of a sludge plume from the point of disposal to the site boundary.

2. To assess water quality conditions during the summer at selected reference stations.

3. To collect hydrographic and current data in the vicinity of the site.

4. To document the occurrence and abundance of endangered species (birds, turtles, and marine mammals) in the vicinity of the site.

Objectives 1 and 2 were concerned with examining the movement of the sludge to and beyond the dumpsite boundary. Information on short-term surface water movement was obtained by tracking surface drogues. This information permitted the field party to designate stations along the upcurrent boundary of the site for the collection of specific sludge tracer samples from an actual sludge plume. The plume-tracking study and the collection of sludge tracer samples at the site boundary are referred to as Dumpsite Boundary Reconnaissance (DBR). Water quality data for specific tracers (total suspended solids (TSS), Clostridium perfringens, and trace metals) were obtained at the site boundary and at selected reference stations. Trace metals samples collected as part of the DBR study were not analyzed. The results obtained at the site boundary are compared with data from reference stations and historical baseline data to determine the potential transport of detectable quantities of sludge beyond the site boundary.

Objective 3 was concerned with characterizing the structure of the water column and determining current measurements over a six-month period. The moored current meters provide data on the long-term movement (speed and direction) of surface (from 50 to 150 m) and subpycnoline (from 500 to 2450 m) water. These data have been lacking at the site, although models describing sludge movement have assumed a net southwesterly flow. Data on the movement of water masses at the site were needed to understand the transport of disposed sludge and to address issues related to a) the design of monitoring program activities, b) the potential direction of movement of the sludge (i.e., towards the shoreline), and c) the flow of water through the site. The results of the current meter measurements are presented and discussed in a separate report (Battelle, 1987b).

Data collected to meet the requirements of Objective 4 will be used to assess seasonal distributions and abundances of marine mammals, turtles, and birds at the site. to assess seasonal distributions. Data on summer abundances were sparse.

1.3 SCOPE OF THE REPORT

This report discusses all survey activities completed during Legs I and II of the 1986 summer survey at the 106-Mile Site. In addition, this document presents the results and interpretation of the laboratory analysis and survey data within the framework of the monitoring program for the 106-Mile Site. Chapter 2 describes the dumpsite and the location of all DBR, reference water quality, and current meter mooring stations. Chapter 3 describes the field and laboratory methods used to collect and analyze all survey data. All survey results are presented in Chapter 4. In Chapter 5, the results are discussed, conclusions are drawn, and appropriate recommendations are made.

2.0 STUDY AREA

2.1 SITE DESCRIPTION

The area designated by EPA for disposal of sewage sludge is the eastern portion of the Interim 106-Mile Site, located near the 2500-m isobath approximately 120 nmi southeast of Ambrose Light, New York, and 115 nmi east of Atlantic City, New Jersey. The area of the site is approximately 100 nmi^2; the site is bounded by latitudes 38°40'N to 39°00'N and longitudes 72°00'W to 72°05'W. The location of the site is shown in Figure 1.

The 106-Mile Site is a designated U.S. deepwater dumpsite for the ocean disposal of sewage sludge. EPA designated this site because it meets all specified requirements of the MPRSA of 1972 for site designation. The site is not located in an area of significant commercial or recreational fish or shellfish harvesting. The currents near the site, the deep permanent pycnocline, and the great distance from shore ensure that impacts associated with ocean dumping at the site will be minimal.

2.2 STATION LOCATIONS

The locations of all stations occupied at the 106-Mile Site during both legs of the 1986 summer survey are shown in Figure 2. The coordinates for each station are presented in Table 2. During Leg I of the survey, sampling activities were completed at Stations D10-1, DBR-1, DBR-2, and DBR-3 (DBR stations) and A-3, A-5, and A-7 (reference water quality stations). During Leg II, current meter moorings were deployed at Stations A-5 and A-9.

Sampling activities for the DBR study were originally planned (Battelle, 1986b) at 10 DBR stations spaced at 0.5-nmi intervals along the dumpsite boundary. The specific locations at these DBR stations were determined by tracking drogues (at 10, 30, and 75 m) to determine the speed and direction of the water mass.

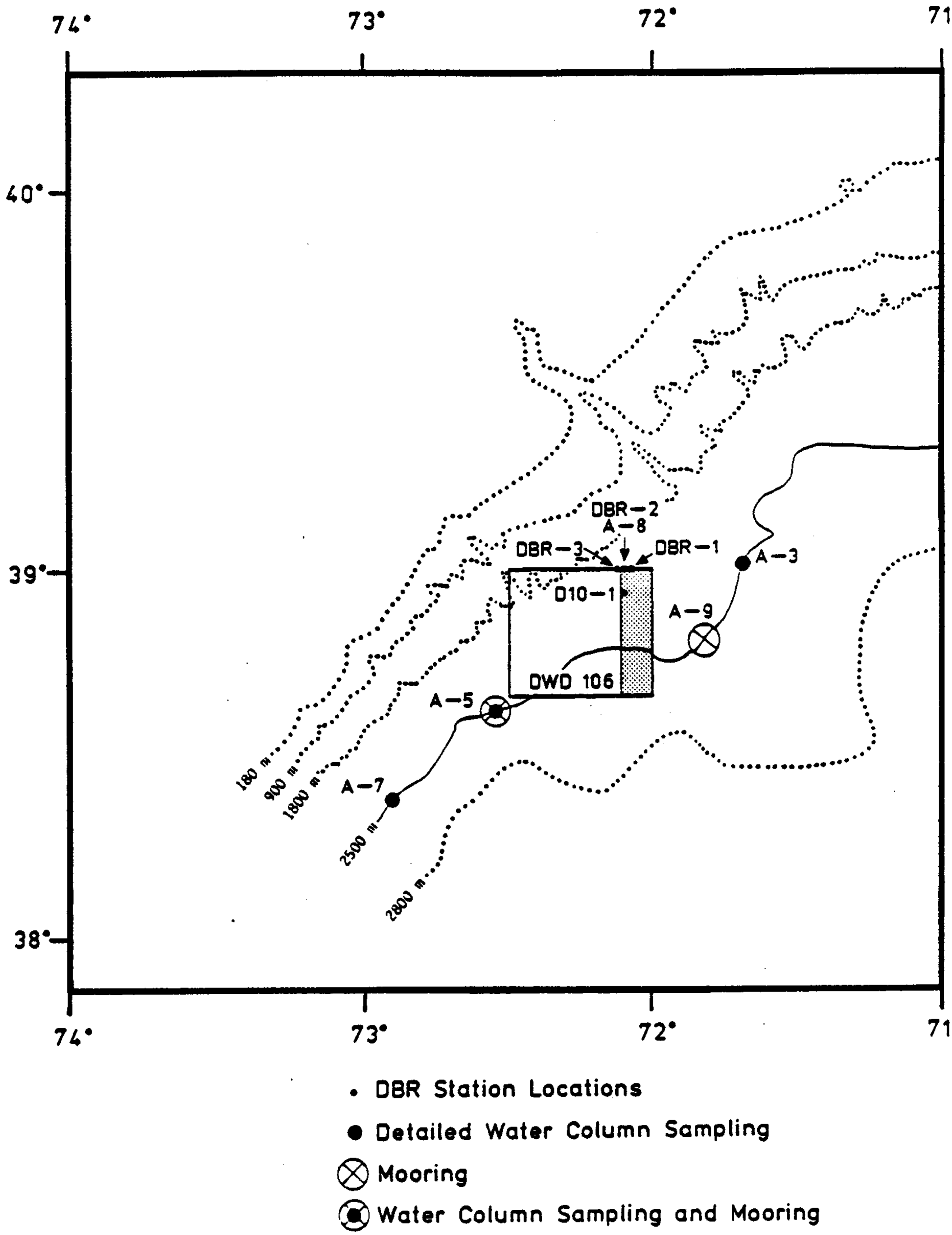

FIGURE 2. STATIONS OCCUPIED AT THE 106-MILE SITE DURING THE 1986 SUMMER SURVEY (SHADED AREA INDICATES THE 106-MILE SEWAGE SLUDGE DISPOSAL SITE)

TABLE 2. COORDINATES FOR STATIONS SAMPLED DURING THE 106-MILE SITE 1986 SUMMER SURVEY

Station	Latitude/ Longitude	LORAN C Time Delays
D10-1[1]	-	26080.8 42811.7
DBR-1[1]	-	26078.4 42834.1
DBR-2[1]	-	26080.0 42832.8
DBR-3[1]	-	26079.5 42830.7
A-3[1]	39°01'N 71°39'W	25927.0 42845.0
A-5[1]	38°36'N 72°35'W	26260.4 42605.2
A-5[2]	38°34.49'N 72°36.63'W	26273.4 42586.0
A-7[1]	38°22'N 72°55'W	26374.4 42501.1
A-9[2]	38°54.39'N 71°51.67'W	26005.4 42783.1

\- indicates that latitude/longitude is not available for the designated stations.

[1]Water column station coordinates.

[2]Current meter mooring stations

The results of this short-term DBR study, discussed in detail in Chapter 4, indicated that the water mass at the site was traveling to the north at a speed of approximately 1 nautical mile per hour, or 1 knot. Before initiating the DBR study, the EPA chief scientist and the Battelle second scientist decided that because of time constraints and the flow speed of the plume, it would be difficult to collect samples from 10 stations at the dumpsite boundary. As a result, the number of DBR stations (DBR-1, DBR-2, and DBR-3) along the northern boundary of the dumpsite was reduced from 10 to 3 (Figure 2). A fourth station (D10-1) marked the location of the start of the sludge plume tracking activity and was included as part of the DBR study.

Stations A-3, A-5, and A-7 were selected as reference stations for acquiring additional background data on water quality near the site. These stations were established by EPA and were sampled during previous baseline studies. All three stations lie on the 2500-m isobath. Station A-3 is located approximately 10 nmi upcurrent (northeast) of the actual dumpsite. Station A-5 (a reference and current meter mooring station) is approximately 20 nmi downcurrent (southwest) of the dumpsite. Station A-7 is located approximately 40 nmi downcurrent (southwest) of the dumpsite.

3.0 SURVEY ACTIVITIES FIELD METHODS FOR SAMPLE AND DATA COLLECTION, AND LABORATORY METHODS FOR SAMPLE PREPARATION AND ANALYSIS

This chapter has been divided into three sections. Section 3.1 discusses all sampling and data collection activities conducted during the survey. Section 3.2 discusses the methods used to acquire and collect samples during the survey at the 106-Mile Site. Section 3.3 briefly describes all laboratory preparation and analytical procedures used to analyze samples collected during the survey. Many of the sampling and analytical procedures discussed below are detailed in EPA Standard Operating Procedures (SOPs) (Battelle, 1987b,c).

3.1 SURVEY SAMPLING ACTIVITIES

During Leg 1 of the survey at the 106-Mile Site, activities were conducted to collect nearfield sludge tracer data (from actual sewage sludge plume) at the dumpsite and to collect reference (baseline) water quality data at selected stations outside the dumpsite boundary. During Leg 2 of the survey, two current meter mooring arrays were deployed at selected stations outside the dumpsite. The arrays were positioned to acquire long-term (over a six-month period) current meter data in the vicinity of the sludge disposal site. The tracks for each leg of the survey are shown in Figure 3. With minor exceptions, all survey activities were completed. The activities are briefly summarized below, with respect to each objective (Section 1.2).

To accomplish Objective 1 (Preliminary Study of the Movement of the Sludge Plume: Dumpsite Boundary Reconnaissance (DBR)), activities were designed to track an actual sewage sludge plume from the point of disposal (Station D10-1) to the dumpsite boundary (Stations DBR-1, DBR-2, and DBR-3). In addition, activities were designed to collect samples for analysis of specific sludge tracers (total suspended solids (TSS), *Clostridium perfringens*, and trace metals) from each of the DBR stations (D10-1, DBR-1, DBR-2, and DBR-3). The following activities were completed as part of the DBR study:

> Before sludge was dumped by a preselected barge, drogues set at depths of 10, 30, and 75 m were tracked to

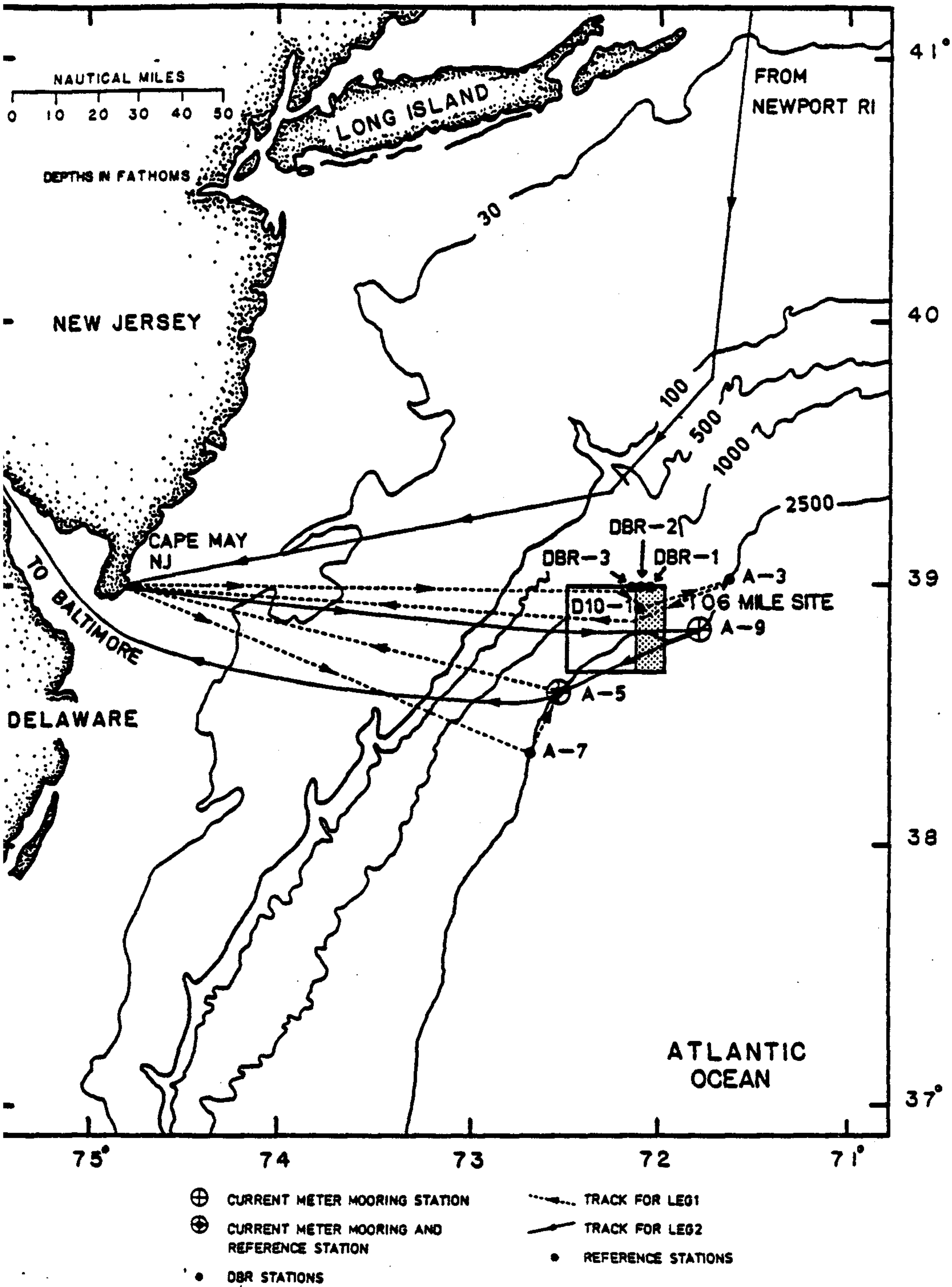

FIGURE 3. SURVEY TRACK FOLLOWED DURING THE 106-MILE SITE 1986 SUMMER SURVEY

determine the direction and speed of the surface water mass at the site, in order to establish the locations of the DBR stations (D10-1, DBR-1, DBR-2, and DBR-3). After the sludge was dumped, seawater samples were collected from each DBR station as the sludge plume proceeded from the point of disposal (D10-1) and crossed the dumpsite boundary. Samples were collected at three depths, 10, 30, and 75 m, for analysis of sludge tracers.

To accomplish Objective 2 (Assessment of Water Quality at Selected Reference Stations), activities were designed to assess baseline water quality data from selected reference stations. High-volume surface (10 m) and subpycnocline (250 m) water samples were collected at three reference stations (A-3, A-5, and A-7) for analysis of a suite of organic constituents (see Table 1). In addition, surface (10 m) and subpycnocline (250 m) water samples were collected for the analysis of the water quality, *C. perfringens*, and trace metals also listed in Table 1.

To accomplish Objective 3 (Water Column Structure and Currents), expendable bathythermograph (XBT) and conductivity-temperature-depth (CTD) profiles were taken to determine water column structure. Current meter moorings were deployed to determine current direction and speed over a six-month period and to determine long-term water mass movement around the site. In addition, large-scale water mass movement was observed at the site using satellite imagery prior to and during the survey.

To accomplish Objective 4 (Endangered Species Observations), a certified observer for endangered species of whales, marine turtles, and seabirds noted the occurrences of such species at the site and along the survey track.

3.2 METHODS FOR FIELD SAMPLE COLLECTION, SAMPLE PROCESSING, AND DATA AQUISITION

This section briefly discusses the methods used for the shipboard collection and processing of data and water samples obtained during both legs of the survey. The first part of this section describes the collection of data and samples during Leg I. The second part briefly describes procedures used to deploy the current meter moorings during Leg II.

For Leg 1 activities, methods for collecting XBT data are described first, followed by a discussion of drogue and plume tracking methods. In addition, this section presents methods used for collecting and processing sludge tracer (DBR) and reference station water samples (for analysis of organic compounds, trace metals, water quality parameters, and *C. perfringens*). This section also describes the techniques used to monitor the presence and determine the abundance of cetaceans, turtles, and seabirds in the 106-Mile Site and vicinity. For Leg II activities, methods for locating the 2500-m isobath are initially discussed, followed by a discussion of the methods for assembling and deploying the current meter mooring at selected stations.

3.2.1 Field Sampling and Data Acquisition During Leg I of the Survey

3.2.1.1 XBT DEPLOYMENT AND RECORDING PROCEDURES

At the location of initial dumping of sewage sludge (start of the DBR study), and upon arrival at each reference station, an expendable bathythermograph (XBT) was released to record temperature vs. depth profiles. Profiles were recorded from the surface to a depth of 2000 m. This activity was done to determine the location of the thermocline and to obtain information on the vertical structure of the water column in the dumpsite and vicinity. The XBT equipment, including probe release gun, the recording instrument, and software, was provided by the OSV *Peter W. Anderson*.

3.2.1.2 SATELLITE IMAGERY DATA ACQUISITION

Before and during the survey, satellite imagery data showing surface water temperatures were obtained from National Oceanic and Atmospheric

Administration (NOAA) to help determine the characteristics of the surface water at the site.

3.2.1.3 DROGUE AND PLUME TRACKING PROCEDURES

Drogues set at depths of 10, 30, and 75 m were deployed and tracked within the boundaries of the 106-Mile Site to determine the direction and speed of the currents at the site. The drogues were deployed near the center of the site and tracked until rendezvous with the sludge barge. The drogues were retrieved and a 10-m drogue was redeployed and tracked until it crossed the northern site boundary. Based on the results of the preliminary drogue tracking study, appropriate locations for the DBR stations (for collecting sludge tracer samples) were selected. In addition, surface (10-m) drogues were tracked at reference Stations A-3 and A-7 to confirm the results obtained during the DBR study (discussed in Section 4.0).

The drogues consisted of four canvas panels stretched between 4'x 4' perpendicular frames (connected in the center by cross pieces) constructed from polyvinyl chloride (PVC) tubing. A schematic of the drogue is shown in Figure 4. Piano wire cut to the desired length (10, 30, or 75 m) was used to attach the drogue to a surface float. A weight was attached to the bottom of the drogue frame to submerge the drogue to the desired depth.

The drogues were tracked using radio direction finding (RDF) transmitting and receiving equipment supplied by the OSV Peter W. Anderson. A battery operated transmitter of a specific frequency was attached to the surface float of each drogue. The RDF receiving equipment was capable of independently detecting and locating the bearing of each specific transmitter frequency.

Each drogue was deployed float first to prevent possible breakage of the piano wire and subsequent loss of the drogues. After the entire length of piano wire for each drogue was deployed, the drogue and weight were dropped from the fantail of the ship. The drogues were tracked by sight and RDF. Drogue coordinates (for DBR and reference stations) were marked at specific time intervals, generally every 15 minutes from the time of deployment (T=0).

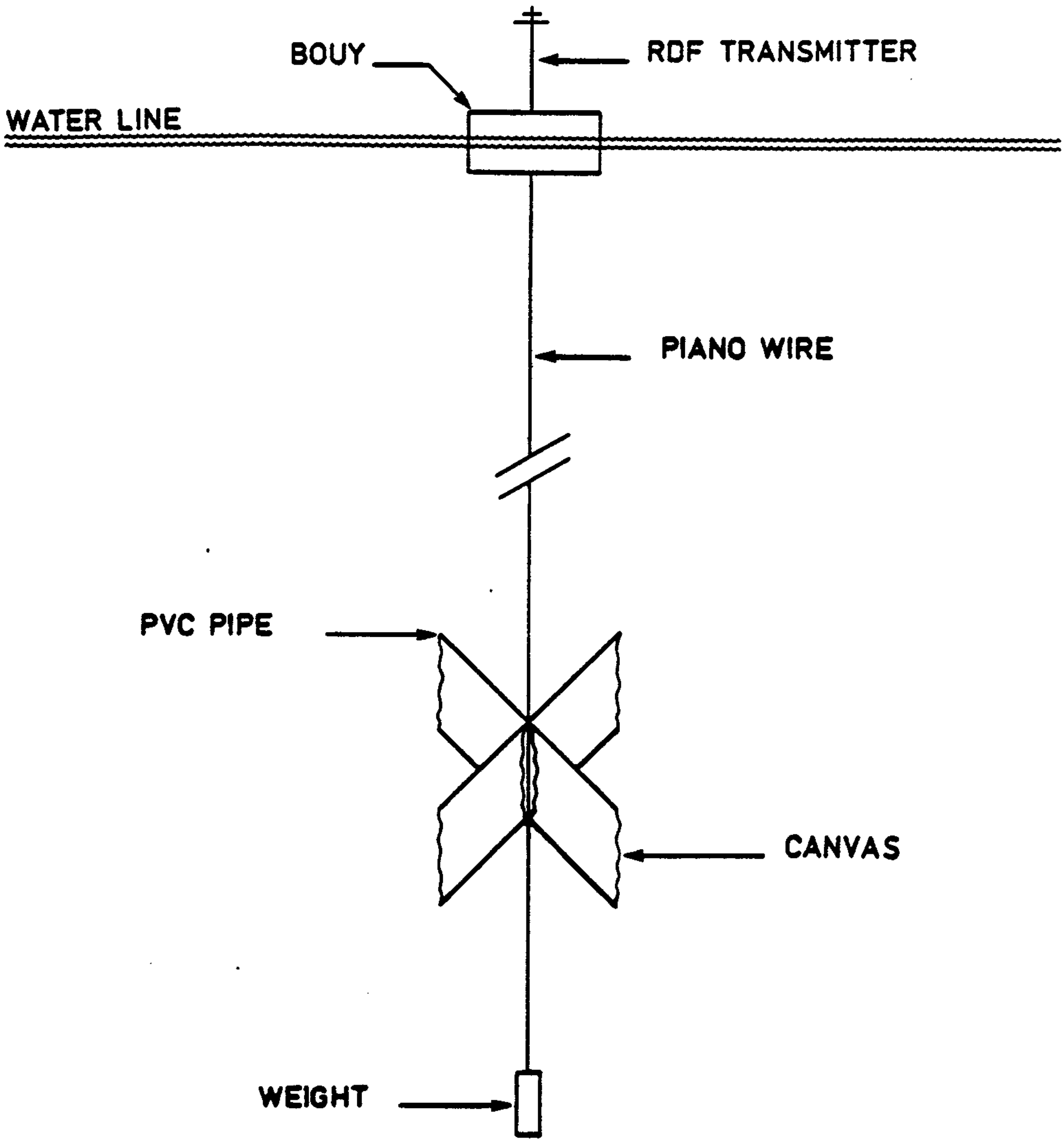

FIGURE 4 SCHEMATIC DIAGRAM OF THE DROGUE

The series of drogue coordinates acquired from each station (DBR + reference station) were complied to produce drogue or plume tracks for those stations.

3.2.1.4 WATER SAMPLING AT DBR STATIONS FOR SLUDGE TRACERS

At each of the DBR stations (D10-1, DBR-1, DBR-2, and DBR-3) water samples were collected from a sewage sludge plume at depths of 10, 30, and 75 m. The samples were processed for analysis of selected sludge tracers (TSS and *C. perfringens*). In addition, trace metals samples were collected at each DBR station. Table 3 indicates the type and number of samples collected at each DBR station. The following discusses the methods for collecting and processing TSS, *C. perfringens*, and trace metals samples.

- **Total Suspended Solids (TSS)**

  Samples for total suspended solids were collected using 30-L GO-FLO bottles at depths of 10, 30, and 75 m. At Station DBR-1, TSS samples were processed and analyzed in triplicate. At Stations D10-1, DBR-2, and DBR-3, only one sample from each depth was processed and analyzed. A 4-L subsample was taken from each GO-FLO bottle designated for TSS analysis. Each 4-L subsample was filtered through a preweighed 0.45-µm membrane filter (or until the pores clogged).

- ***Clostridium perfringens***

  Samples for *C. perfringens* analysis were collected using a 30-L GO-FLO bottle sterilized with ethanol. Subsamples of 1.0, 0.5 and 0.1 L were filtered through presterilized, 0.45-µm filters. Filters were placed onto petri dishes containing sterile mCP media and incubated anaerobically at 44.5°C for 18-24 hours.

- **Trace Metals**

  Surface water samples were collected in the visible sludge plume at each DBR station (D10-1, DBR-1, DBR-2, and DBR-3) and analyzed for trace metals. Two samples were collected at D10-1 using an acid-cleaned bucket to prevent possible high-level contamination of the specially treated (acid-cleaned and Teflon-lined) GO-

TABLE 3. SUMMARY OF ALL SAMPLES AND DATA COLLECTED DURING THE PLUME TRACKING AND DBR PHASES OF THE 106-MILE SITE 1986 SUMMER SURVEY

Parameters	D10-1[a] 10 m	D10-1[a] 30 m	D10-1[a] 75 m	DBR-1[b] 10 m	DBR-1[b] 30 m	DBR-1[b] 75 m	DBR-2 10 m	DBR-2 30 m	DBR-2 75 m	DBR-3 10 m	DBR-3 30 m	DBR-3 75 m	Total DBR Samples Collected
TSS	3	1	1	3	3	3	1	-[c]	1	1	1	1	19
Micro	3	1	1	3	3	3	1	-	1	1	1	1	19
Metals	2			1			1			1			5
XBT	1												1
CTD	1			1			1			1			4

[a]D10-1 = Plume/drogue tracking station.
[b]DBR = Dumpsite boundary reconnaissance stations.

[c]- Indicates that sample collections were attempted, but no samples were obtained.

FLO bottles by the concentrated sludge plume. A specially treated GO-FLO bottle was used to collect trace metal samples from stations (DBR-1, DBR-2, and DBR-3) in the more dilute sludge plume at the dumpsite boundary. The bottle was attached to a clean nylon line and deployed from the fantail of the ship. When the bottle was lowered to 15 meters, it was opened by a pressure sensing trigger. The bottle was triggered to the closed position using a brass messanger. A single surface water sample was collected at each of the three DBR stations (DBR-1, DBR-2, and DBR-3) using the GO-FLO bottle.

The samples were transported into a specially constructed clean room for processing. The sludge water samples were drained from the GO-FLO bottle into acid-cleaned 2-L polyethylene bottles for subsequent analysis of selected trace metals (Ag, Cd, Cr, Fe, Pb, and Zn), and into acid-cleaned 1-L glass bottles for Hg analysis. Teflon fitting and tubing were used to connect the vent at the top of the GO-FLO to a cylinder of purified nitrogen. The nitrogen was filtered through a 0.4-μm in-line membrane filter. The nitrogen applied a slight positive pressure (2-3 psi) to the GO-FLO bottle during subsample transfer to prevent possible contaminants from entering the bottle. All subsamples were acidified with double-distilled nitric acid immediately after collection. Trace metal samples collected during the DBR study were not analyzed.

3.2.1.5 WATER SAMPLING AT SELECTED REFERENCE STATIONS

At each of three reference stations (A-3, A-5, and A-7,) in the vicinity of the 106-Mile Site, seawater samples were collected from the surface (10 m) and below the pycnocline (250 m) using two techniques: 1) high-volume water sampling using a stainless steel pumping system and 2) hydrocasts using GO-FLO sample bottles. A high-volume water sampler (Battelle, 1987b) was used to sample surface and subpycnocline water for selected organic compounds. The high-volume water sampler was used in conjunction with a water-solvent extraction system on board the vessel. This system processed, at sea, large volumes of water for the analysis of selected organic constituents. Using 30-L GO-FLO sample bottles, hydrocasts were conducted to collect surface and subpycnocline water samples for a variety of parameters.

These parameters included water quality and biochemical parameters, trace metals, and _C. perfringens_. A summary of samples collected at each reference station is listed in Table 4.

- **Sampling and Processing for Organic Compounds**

Seawater analyzed for organic constituents was sampled from depths of 10 m (surface) and 250 m (subpycnocline) using a high-volume water sampling system. The system consists of an intake line composed of 1 inch O.D. stainless steel (SS) tubing (enough to sample below the pycnocline), a stainless steel centrifugal pump, a 0.3-μm in-line filter held in place with a 293-mm filter holder, and a 1000-L extraction container. The stainless steel tubing for sample intake was composed of alternating sections of 20' straight tubing and 4' flex tubing.

At each selected reference station, the tubing was assembled and deployed to a depth of 250 m for subpycnocline sampling. The tubing was secured with clamps to the ship's trawl cable.

Sample water was pumped with a centrifugal pump into the extraction container. As the sample water traveled to the container, it was filtered through a 0.3-μm precombusted (400^{o}C) glass-fiber filter. Sampling operations were continued until the container was filled with 900 to 950 L of filtered seawater at a rate of 16 to 20 L/min. After sampling operations for subpycnocline seawater were completed, the intake tubing was disassembled and retreived until the nozzle extended 10 m below the seasurface (for surface sampling). The 10-m high-volume sample was collected in the same manner as the subpycnocline sample.

Each sample was processed in a high-volume extraction container as briefly described below:

a. A spike solution was added to the filtered water of selected samples immediately after the extraction container was filled. Spiked water was agitated with two mixers for 30 minutes.

b. Twelve liters of methylene chloride (DCM) were added to the seawater samples (spiked or unspiked) to the saturation point.

TABLE 4. SUMMARY OF ALL SAMPLES AND DATA COLLECTED DURING THE REFERENCE SAMPLING AND MOORING DEPLOYMENT PHASES OF THE 106-MILE SITE SURVEY--SUMMER 1986.

Parameter	Station A-3 10 m	Station A-3 250 m	Station A-7 10 m	Station A-7 250 m	Station A-5 10 m	Station A-5 250 m	Station A-5 2500 m	Station A-9 2500 m	Total Reference Samples Collected	Total DBR Samples Collected (From Table 3)	Total Samples Collected
TSS	3	3	3	3	3	3			18	19	37
Microbiology	3	3	3	3	3	3			18	19	37
ATP	3	3	3	3	3	3			18		18
Chlorophyll a	3	3	3	3	3	3			18		18
Turbidity	3	3	3	3	3	3			18		18
pH	3	3	3	3	3	3			18		18
Salinity	3	3	3	3	3	3			18		18
Dissolved Oxygen	3	3	3	3	-[a]	-			4		4
Organics Dissolved	1	1	1	1	1	1			6		6
Organics Particulate	1	1	1	1	1	1			6		6
Metals	-	-	3	3	-	2			8	5	13
CTD	1		-		1				2	4	6
XBT	1		1		1		1	1	5	1	6
Moorings Deployed							1	1	2		2

[a]- Indicates that sample collections were attempted, but no samples were obtained.

c. An additional 4L of DCM was added and the water was agitated for 25 minutes with both mixers. The phases were allowed to separate for 45 minutes. The solvent was decanted through the T-valve at the bottom of the container into a 4-L amber-glass bottle.

d. Step C was repeated two times.

   Each extract volume (three per sample) was decanted into separate bottles for storage. The cap of each bottle was wrapped with Teflon tape followed by electrical tape.

One sample blank (collected as the fourth extract) was taken to determine potential sample contaminants contributed during the extraction process. In addition, one solvent trip blank was collected to determine possible contaminants contributed during addition of the extraction solvents to the samples. However, neither sample was analyzed.

Three filter wipe samples for analysis of organic constituents were collected from different locations on the research vessel. The samples were taken to identify possible ship-produced organic contaminants that may be present in the sample.

Wipe samples were taken with a muffled 293-mm filter for filtering particulates from water samples for organic constituents. A 6" x 6" area was wiped from each sampled surface. These surfaces included 1) the deck in the vicinity of the extraction tank (W-1), 2) the top of the extraction container (W-2) and 3) the processing laboratory (W-3). The samples were placed in solvent-rinsed and muffled glass jars, and stored in the freezer until analysis.

- **Water Quality and Biochemical Parameters, and *C. perfringens***

To acquire additional baseline data, water quality and biochemical parameters were sampled at each of the reference stations. Samples were analyzed on the ship for the following water quality parameters: temperature, salinity dissolved oxygen, pH, and turbidity. In addition, the biochemical parameter chlorophyll "a" was analyzed aboard the survey vessel. The water quality parameter, TSS, and the biochemical

Data were recorded into two major categories: location/ environment and species/behavior. Each category was recorded for each 15-min period, and both categories were identified by a unique survey and observation number. Location/environmental data included latitude-longitude (deg-min); start time (yr-mo-day-h-min); elapsed time (min); vessel speed (kn) and course (deg N); water depth (m) and temperature (° C); barometric pressure trend; visibility; and wind direction (deg N) and speed (kn). Species/behavior data included species group (mammal, turtle, or bird), species identification, numbers seen, age color phase (bird only), oil (bird only), distance and angle to sightings (mammals and turtles only), heading, animal association, debris association, and behavior (Miller et al., 1980).

3.2.2 Field Sampling and Data Aquisition During Leg II of the 106-Mile Site Survey

During Leg II of the survey, two mooring arrays for current meters were deployed at Stations A-5 and A-9 (south and north, respectively). Because the current meter data will not be presented in this report, the methods for deploying the moorings will not be discussed in this report. All data and methods for deploying the mooring are detailed in Battelle, 1987b.

3.3 METHODS FOR LABORATORY SAMPLE PREPARATION AND ANALYSIS

Methods for the preparation and analysis of water samples collected during the survey are briefly summarized below. All DBR seawater samples were analyzed for TSS and *C. perfringens*. The analyses performed on all seawater samples from the three reference stations (A-3, A-5, and A-7) included 1) determination of total (unfiltered) trace metals, 2) determination of organic constituents (particulate and filtrate), 3) determination of water quality constituents (salinity, dissolved oxygen, turbidity, pH, TSS, and temperature), 4) determination of biochemical parameters (chlorophyll *a* and ATP), and 5) enumeration of *C. perfringens*. Samples were analyzed for the following parameters at a shore-based laboratory: organic compounds, trace metals, TSS, and ATP . Sample analysis for the rest of the water quality parameters (salinity, dissolved oxygen, turbidity, pH, and temperature), chlorophyll *a*, and *C. perfringens* were conducted at sea aboard the OSV *Peter W. Anderson*.

3.3.1 Analysis of Selected Organic Compounds

Samples of surface and subpycnocline seawater were collected using the high-volume water sampler. Samples were collected from three reference stations for analysis of particulate and dissolved organic constituents. To initiate sample processing, a preliminary high-volume extraction was performed on each dissolved fraction in a 1000-L extraction container.

3.3.1.1 PREPARATION OF SAMPLES

Filtrate Extracts. Seawater sample extracts were partially processed aboard ship. The extracts were returned to the laboratory for further processing and analysis of trace organic constituents. The DCM extracts were combined using Kuderna-Danish evaporative techniques. The concentrated extracts were processed through silica-alumina column chromatography and separate fractions were collected for PAH/pesticides/PCB and coprostanol analyses.

Filters. Filters were extracted in the laboratory with DCM. The DCM extracts of the filters and the large volumes of seawater filtrates were concentrated using Kuderna-Danish apparatus. The concentrated extracts were then processed through silica-alumina column chromatography to remove interfering substances and to separate fractions for PAH/pesticide/PCB and coprostanol analysis.

3.3.1.2 ANALYSIS OF SAMPLES

The following section briefly describes the methods used for analysis of coprostanol, PCBs and pesticides, PAHs and BEPH.

- **Coprostanol**

  The polar fraction (f3) from the column chromatography procedure was analyzed for coprostanol by gas chromatography using flame ionization detection (GC/FID). A calibration curve was determined by analyzing standards over a range of concentrations. During analysis, the routine calibration was performed every eight hours by analyzing one of the calibration standards.

- **Pesticides and PCBs**

  A subsample of the neutral (non-polar) fraction including the combined f_1 and f_2 fractions from the column chromatography procedure was analyzed for pesticides and PCB chlorination by gas chromatography using capillary column electron capture detection (GC/ECD) with a DB-5 capillary column (J&W Scientific, Inc.). Confirmation analysis for pesticides was performed using GC/ECD with a DB-17 capillary column (J&W Scientific, Inc.) Quantification was performed by adding an internal standard (dibromooctafluorobiphenyl) to each sample. Response factors for each compound relative to the internal standard were determined before the start of analysis.

- **PAHs and Phthalate**

  A subsample of the neutral fraction was analyzed for polycyclic aromatic hydrocarbons (PAH) and bis(2-ethylhexyl) phthalate (BEPH) by capillary WCOT column gas chromatography/mass spectroscopy (GC/MS). PAHs and phthalate were identified by comparing retention times and mass spectra of unknown compounds to those compounds. A calibration curve was established by analyzing calibration standards of known compounds and calculating response factors relative to an internal standard (d_{12}-chrysene). The internal standard was added to each sample before sample preparation and carried through all phases of sample work up.

3.3.2 Analysis of Water Quality and Biochemical Parameters

3.3.2.1 WATER QUALITY PARAMETERS

Samples collected by the hydrocasts at each reference station were processed and analyzed aboard the OSV Peter W. Anderson for the water quality and biochemical parameters (salinity, dissolved oxygen, pH, turbidity, temperature, chlorophyll a, and phaeophytin). ATP and TSS were the only parameters for which samples were processed aboard ship and later analyzed in an onshore laboratory. Samples collected for TSS analysis at each DBR station were processed aboard the survey vessel and analyzed at an on-shore laboratory.

All water quality samples were processed and analyzed in triplicate. The instruments and most of the supplies used to analyze these water quality and biochemical parameters aboard ship are part of the equipment and supply inventory of the OSV Peter W. Anderson. The following methods for the shipboard processing and analysis of water samples for salinity, dissolved oxygen, pH, turbidity, and TSS are briefly described.

- **Salinity**

  Salinity was determined in discrete water samples with the Beckman Model RS-7C Induction Salinometer. Copenhagen water was used to calibrate the instrument at the start of the survey and as a control sample with each set of samples analyzed.

- **Dissolved Oxygen**

  Dissolved oxygen (DO) in seawater was measured with the YSI Model 57 Dissolved Oxygen Meter. DO aliquots were taken from the GO-FLO sample bottles before other samples. Analysis was conducted within 15 minutes of sample collection. Deionized water and seawater were used as controls; air calibrations were also made.

- **pH**

  Seawater pH was determined with the Beckman Model 4500 pH Meter. Subsamples for pH were taken from the GO-FLO bottles for each depth (10 and 250 m). Performance check and calibration of the pH meter were conducted at the start of the survey and before each set of samples.

- **Turbidity**

  The seawater turidity was determined with the Hach Model 2100 Turbidometer. The instrument was calibrated before each set of samples using a commercial turbidity standard.

- **Total Suspended Solids (TSS)**

  Total suspended solids (TSS) samples were collected by filtering 4L of seawater through 0.45-μm membrane filters. The filters were stored at -20°C until analysis. In the laboratory, the filters were air dried for 24 hours and weighed on a Mettler analytical balance.

3.3.2.2 BIOCHEMICAL PARAMETERS

The procedures for processing and analyzing ATP and chlorophyll a samples are briefly discussed below.

- **ATP**

  Adenosine triphosphate (ATP) samples were collected by filtering 4L of seawater through sterile glass fiber filters. The filters were then extracted with boiling Tris-Buffer and the extracts were frozen (20°C) until analysis. After thawing, luciferin was added to the extracts. ATP was quantified by liquid scintillation counting of the light emission from the preparation complex of the ATP-enzyme.

  ATP filter blanks or procedural blanks (no deionized water was processed through the filters) were processed and treated as sample filters. A volume of 4L was assumed for the sample blanks.

- **Chlorophyll a and Phaeophytin**

  Sample preparation, extraction, and the analysis of chlorophyll a and phaeophytin, using the Turner Model 1000 Fluorometer, were conducted at sea. Water samples were filtered on a 47-mm GF/C glass-fiber filter. The cells were disintegrated by freezing the filters in acetone. After thawing, the slurry was centrifuged, and the supernatant decanted into a clean culture tube for analysis. By obtaining fluorometer readings before and after acidification of the samples, both chlorophyll a and phaeophytin were determined. Analytical standards were prepared from a commercial chlorophyll a stock solution. The linearity curve and r calibration factor of the working standards were analyzed with each set of samples.

3.3.3 Analysis of *Clostridium perfringens*

The number of *C. perfringens* spores in seawater was determined for samples collected from reference and DBR stations. Spores were collected by filtering aliquots of seawater (0.1, 0.5, and 1.0 L) through 0.45-μm membrane filters. The filters were placed in petri dishes containing modified *C. perfringens* (m-CP) media and incubated at 44.5°C (± 0.2) for 18-24 hours. Confirmation was performed by exposing the incubated plates to ammonium hydroxide vapors, causing *C.perfingens* colonies to turn a magenta color. The bacterial colonies were enumerated under a dissection microscope and the numbers were recorded for each sample aliquot. The colony counts for each aliquot are reported as counts/100 ml and calculated by the following formula:

$$\text{Colonies/100 m} = \frac{\text{Number of Plate Colonies}}{\text{Volume of Seawater Filtered}} \times 100$$

3.3.4 Analysis of Trace Metals

Seawater samples for analysis of trace metals were collected in triplicate from the surface and below the pycnocline at reference Station A-7. Two subpycnocline samples were collected at reference Station A-5. Five samples were collected for trace metals analysis during the DBR phase of the survey, but the analysis of those samples was not funded. The reference station samples analyzed for trace metals were collected using an acid-cleaned, Teflon-lined GO-FLO bottle.

3.3.4.1 SILVER

Silver (Ag) was analyzed by direct injection of the unfiltered seawater sample into a graphite furnace atomic absorption spectrophotometry (GFAAS). The standard additions method was used to quantify the silver in each sample. This method compares the reading obtained from a sample with no addition, to readings obtained when known amounts of silver are added to the sample.

3.3.4.2 CADMIUM, SILVER, COPPER, IRON, LEAD, AND ZINC

Unfiltered seawater samples were extracted at pH 4 using a 1 percent solution of purified ammonium-1-pyrrolidine dithiocarbamate-diethylammonium diethyldithiocarbamate (APDC-DDDC) and 20 ml of freon. The metals were back extracted into hot nitric acid. The nitric acid solutions were then analyzed for cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), and zinc (Zn) by GFAAS.

3.3.4.3 CHROMIUM

The procedure for the determination of total dissolved chromium (Cr) is a modification of the methods described by Cranston and Murray (1977). Cr was coprecipitated with 0.01N $Fe(OH)_2$ in aliquots of unfiltered seawater at pH 8. The precipitate was filtered, then digested with 6N hydrochloric acid. After dilution with deionized water, the acid digests were analyzed by GFAAS.

3.3.5 Analysis of Cetaceans, Marine Turtles, and Seabirds

From the observation data collected on the 106-Mile Site 1986 summer survey, the following determinations were made:

- Behavior and directional movements of cetaceans.
- Distribution and abundance of cetaceans and turtles.
- Correlation of physical oceanographic parameters, principally salinity, temperature, and depth, with cetacean and turtle distributions and abundance.
- Comparison of seasonal distribution and abundance (sightings per unit-effort and individuals per unit-effort), and densities (individuals per unit-area) of marine mammals and turtles in the site area.

Estimates of cetacean and turtle abundance were derived from the number of individuals/linear km. During the survey, the initial point of each animal sighting, a radial distance to the sighting, and an angle measurement were determined relative to the transect line. Distance measurements up to 1 km were determined with a hand-held rangefinder (Heinemann, 1981). Sighting distances beyond 1 km were estimated. The ship's radar was used in determining distances to objects near the sighting (e.g., ships, buoys). Angles were estimated from the compass on the bridge of the ship. Right-angle distances were calculated for each sighting from the sighting data. Because sightings of marine mammals and turtles decrease significantly when wind speeds are greater than 17 mph, only data collected when wind speeds were less than 17 mph were examined for this survey.

Estimates of seabird density (birds/km^2) were derived from shipboard data using a strip transect procedure (Powers, 1982; 1983). The sample strip width is determined with a hand-held fixed-interval rangefinder and is defined as 300 m from the designated observation side of the ship and from midship forward to the end of the transect (Heinemann, 1981). Birds passing through the strip for the first time are counted; all transect passes thereafter are considered recounts. Recounts are tallied separately and are not included in the density estimates; however, this method does minimize the inflationary effect on these estimates (Powers, 1982).

Estimates of seabird density were calculated by dividing bird counts from the sampling strip by the area sampled for each transect. Area sampled (A) per transect was calculated as follows:

$$A = \frac{\text{speed (nm/h)}}{60 \text{ min/h}} \times 15 \text{ min} \times \frac{1852 \text{ m}}{1 \text{ nm}} \times 300 \text{ m} \times \frac{1 \text{ km}^2}{1 \times 10^6 \text{m}^2}$$

4.0 QUALITY CONTROL

4.1 DATA QUALITY REQUIREMENTS AND QUALITY ASSURANCE OBJECTIVES

Summaries of the data requirements for the targeted analytes in water samples are presented in Table 5. To verify the accuracy and precision of analytical measurements, method and field blanks were collected and processed. The field blanks were used to determine any background contamination present during field processing and shipping. In addition to blanks, samples spiked with external and internal standards were used to identify any systematic method or operator error. Whenever possible, standard reference materials (SRMs) were included with each set of samples analyzed to confirm the validity of the method used.

Analytical results of spiked samples were used to assess the accuracy of the measurements for the following analytes: PAHs, PCBs, pesticides, coprostanol, and trace metals (Table 5). The accuracy and precision of some measurements (TSS, ATP, chlorophyll *a*, water quality parameters, and *C. perfringens*) could not be estimated using SRMs or spiked samples. Surrogate materials added to water samples during sample preparation were used to evaluate the accuracy of sample preparation procedures. The spikes added immediately before analysis were used to determine the accuracy of the analytical method.

Precision of the analytical measurements was estimated from variation of the results of duplicate, triplicate, or quadruplicate sample analyses. The precision (or standard deviation) was calculated using the following equation:

$$\text{Standard deviation (absolute units)} = \left[\frac{\sum_{i=1}^{n} (x_i-\bar{x})^2}{n-1}\right]^{1/2}$$

where x_i is the experimentally determined value for the ith measurement, n is the number of measurements performed, and $\bar{x}$ is the mean of the experimentally determined values. As with the accuracy determinations, spikes added during sample preparation provide an estimate of sample preparation error, and spikes added immediately before analysis determine the analytical precision.

TABLE 5. OBJECTIVES FOR ANALYTICAL MEASUREMENTS OF SEAWATER SAMPLES.

Parameter	Units	Detection Limit	Accuracy	Precision	Method
Seawater Filtrate or Particulate, Organic Compounds					
Aromatic hydrocarbons, BEHP	µg/L	.001	50	100	Solvent extraction, GC/MS
PCB isomers, pesticides	µg/L	.0001-.005	50	100	Solvent extraction, GC-ECD
Coprostanol	µg/L	.001	50	100	Solvent extraction, GC-FID
Seawater Metals					
Ag	µg/L	.015	50	30	Direct injection
Cd, Zn	µg/L	.015	50	30	Chelation-extraction, GFAA
Cr, Pb, Cu	µg/L	.030	50	30	Chelation-extraction, GFAA
Fe	µg/L	.050	50	30	Chelation-extraction, GFAA
Seawater TSS	mg/L	.01	30	30	Filtration, gravimetric determination
Seawater ATP	µg/L	.01	30	30	Filtration, extraction, LSC
C. perfringens	Spores/100 mL	NA	50	30	Filtration, direct enumeration

4.2 QUALITY CONTROL RESULTS

4.2.1 Water Quality

4.2.1.1 TOTAL SUSPENDED SOLIDS (TSS)

The results of the analysis of five blank filters and the reweighing of selected filters are presented in Tables 6 and 7. The standard deviation (S.D.) demonstrates that the precision of the duplicate weighings is within the limits indicated in Table 5. The blank values are well above the recommended detection limit of 0.01 ng/L, but, in general, below the amounts found in the samples.

4.2.1.2 Adenosine Triphosphate (ATP)

The results of the analysis of procedural blanks and the duplicate analysis (precision) of individual samples are presented in Table 6 and 8. The highest blank value of 0.052 ng/L was well below the recommended detection limit of 10.0 ng/L (0.010 µg/L), indicating that the field and analytical processing did not contribute to ATP levels found in the field. The procedure was very precise, well below the 30 percent precision.

4.2.2 Trace Metals

The results of the analysis of duplicate aliquots (precision) of seawater samples are given in Table 9. The precision of the duplicates was very good for all metals (Ag, Cd, Cr, Cu, Fe, Pb, and Zn), and the results were well within the precision limits given in Table 5. The accuracy of the methods is shown in Table 10 with matrix spike solutions. Spiked concentrations varied from 82 to 115 percent, depending on the metal. These recoveries were well above the 50 percent requirement.

The detection limit objectives for Ag and Pb were not met. Detection limit for Pb was 50 percent higher than the objective. However, the detection limits achieved for all of the elements are several orders of magnitude less than the water quality criteria concentrations.

TABLE 6. ANALYSIS OF PROCEDURAL BLANKS FOR TSS AND ATP[a]

Sample Number	TSS (mg/L)	ATP (ng/L)
1	0.37	0.024
2	0.34	0.042
3	0.10	0.052
4	0.17	0.048
$\bar{x}$[b]	0.24	0.042
S.D.[c]	0.13	0.012

[a]Assumed volume of 4 L for ATP.
[b]$\bar{x}$ = Mean.
[c]S.D. = Standard Deviation.

TABLE 7. DETERMINATION OF PRECISION, DUPLICATE WEIGHINGS OF TSS FILTERS

Station	Depth (meters)	Replicate	TSS Concentration (mg/L) 1	2	$\bar{x}$[a]	S.D.[b]
DBR-1	75	1	0.86	0.79	0.82	0.05
DBR-1	75	2	0.96	0.92	0.94	0.03
DBR-1	10	3	0.78	0.85	0.82	0.05
A-3	10	2	0.30	0.32	0.31	0.01
A-5	10	3	0.92	0.92	0.92	0.00
A-5	250	1	0.70	0.69	0.70	0.01
A-7	10	2	0.16	0.20	0.18	0.03

[a]$\bar{x}$ = Mean.
[b]S.D. = Standard Deviation.

TABLE 10. DETERMINATION OF ACCURACY, TRACE METAL MATRIX SPIKE RECOVERY, SEAWATER ANALYSIS[a]

Spiking Solution	Silver (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Zinc (µg/L)
Amount Expected	20	0.6	1.8	1.0	5.0	1.0	5.0
Amount Recovered Spike No. 1	19	0.7	1.6	1.0	5.1	0.87	5.5
Amount Recovered Spike No. 2	20	0.7	1.6	1.1	5.3	1.0	5.0
$\bar{x}$ Recovery[b]	19.5	0.7	1.6	1.05	5.2	0.94	5.25
Percent Recovery	97.5	116.7	88.9	105.0	104.0	93.5	105.0

[a]Seawater from Station A-7, Replicate 3, depth 10 m.
[b]$\bar{x}$ = Mean.

TABLE 11. DETERMINATION OF ACCURACY FROM RECOVERIES OF SURROGATE ORGANIC COMPOUNDS IN SEAWATER FILTRATE AND PARTICULATE EXTRACTS[a]

Analytes	Station A-3 300 m	A-3 10 m	A-7 250 m	A-7 10 m	A-5 250 m	A-5 10 m	F043[b]	W1[c]	W2[d]	W3[e]
	Filtrates[f]									
Decachlorobiphenyl	40	73	18	39	33	45				
Naphthalene-d_8	26	32	26	21	26	30				
Phenanthrene-d_{10}	51	50	43	56	51	51				
Anthracene-d_{10}	23	26	21	26	32	5				
Perylene-d_{12}	9	5	4	22	18	18				
Androstanol	40.9	51.8	26.9	105.9	65.4	98.8				
	Filters									
Dibromooctafluorobiphenyl	61	95	95	61	65	51	78			
Naphthalene-d8	45	75	48	51	49	51	35			
Phenanthrene-d_{10}	47	100	48	67	59	60	36			
Anthracene-d_{10}	48	87	37	51	51	44	31			
Androstanol	2.1	2.2	118	7.5	13.6	5.2	4.7	7.5	17.5	1.4

[a]Percent recovery.
[b]Procedural blank.
[c]W1 = Wipe sample from deck of ship.
[d]W2 = Wipe sample from top of extraction sample.
[e]W3 = Wipe sample from laboratory.
[f]Dibromooctafluorobiphenyl (DBOFB) was added to both fractions appropriately. However, trichloromethylxylene (used to quantify DBOFB) was added to the filtrate fraction both in the field and just before analysis. This procedure made it impossible to quantify DBOFB in the filtrate fraction.

5.0 RESULTS

This chapter discusses results from the analysis of samples collected for the acquisition of preliminary data on the physical behavior of a sewage sludge plume at the 106-Mile Site. In addition, the results of samples collected as background data from selected reference stations are discussed. The chapter is divided into the following four sections: Satellite Imagery; DBR Study; Reference Stations; and Cetacean, Marine Turtle, and Seabird Observations (Legs I and II). The DBR study section includes the results of drogue tracking, plume tracking, and sludge tracer. The reference station section includes drogue tracking, and organic constituents, XBT, water quality/biochemical, and trace metal results.

5.1 SATELLITE IMAGERY

According to the preliminary evaluation of satellite imagery data, a large warm-core eddy (approximately 150 km in diameter) was observed in the area of the dumpsite during the surveys of 21-28 August and 14-20 September. The eddy was centered at coordinates 39°00'N and 71°30'W east of the northern boundary of the site and remained stationary until 29 August 1986. Surface water currents were expected to flow north. According to the track followed by the drogues, the northward movement of the surface current supported the satellite data. At the beginning of September, the eddy began to move to the southwest along the slope. By 10 September, the northeast quadrant of the eddy was within the site boundaries. At that time, surface current velocities were anticipated to be vigorous and to flow toward the southeast. By 22 September, the eddy was completely clear of the site and continued to move south.

5.2 DBR STUDY

5.2.1 Drogue and Plume Tracking within the Dumpsite

Before sludge was dumped by the preselected barge, the locations of sampling stations for monitoring the sludge plume as it crossed the dumpsite

5.0 RESULTS

This chapter discusses results from the analysis of samples collected for the acquisition of preliminary data on the physical behavior of a sewage sludge plume at the 106-Mile Site. In addition, the results of samples collected as background data from selected reference stations are discussed. The chapter is divided into the following four sections: Satellite Imagery; DBR Study; Reference Stations; and Cetacean, Marine Turtle, and Seabird Observations (Legs I and II). The DBR study section includes the results of drogue tracking, plume tracking, and sludge tracer. The reference station section includes drogue tracking, and organic constituents, XBT, water quality/biochemical, and trace metal results.

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5.2 DBR STUDY

5.2.1 Drogue and Plume Tracking within the Dumpsite

Before sludge was dumped by the preselected barge, the locations of sampling stations for monitoring the sludge plume as it crossed the dumpsite boundary (DBR) were determined by studying the movements of drogues deployed within the site. Because the current speed and direction were unknown at the time of deployment, the drogues were deployed as close as possible to the center of the dumpsite. The drogues, set to depths of 10, 30, and 75 m, were tracked for a period of approximately four hours to determine the speed and direction of the currents at various depths in the mixed layer. The tracks that the drogues followed are presented in Figure 5. The northern boundaries of the site are delineated by diamond-shaped marks at the corners of the site. The drogue track is composed of a series of coordinates (indicated by the "X"s in Figure 5) plotted within specific time intervals (generally every 15 minutes). Time zero (T=0 in Figure 5) indicates the point of deployment for all drogues during the DBR activities.

Because all three drogues remained in close proximity to one another (within a quarter of a mile), the LORAN plotter could not resolve the distance between them. The positions marking the track of the 10-m drogue represent the drift direction for all three drogues. The drogues were carried initially to the north-northwest, at a rate of approximately 1 nmi/h. The track then shifted toward the north and continued in that direction until EPA requested that the sludge barge dump its contents at the location of the 10-m drogue (five miles from the northern boundary on the western edge of the dumpsite, Station D10-1). Throughout the DBR study, the plume (or drogue track after the sludge dump), indicated by the "Y"s in Figure 5, continued to drift to the north.

5.2.2 Sewage Sludge Tracers (TSS and C. Perfringens)

The initiation of the dump marked the beginning of a limited plume sampling activity to determine basic dispersion characteristics of sewage sludge as the plume spread from the point of disposal (Station D10-1) to the dumpsite boundary. The plume boundaries at the surface were clearly visible throughout the DBR activities. Samples were collected for sludge tracers, including collections for total suspended solids (TSS) and

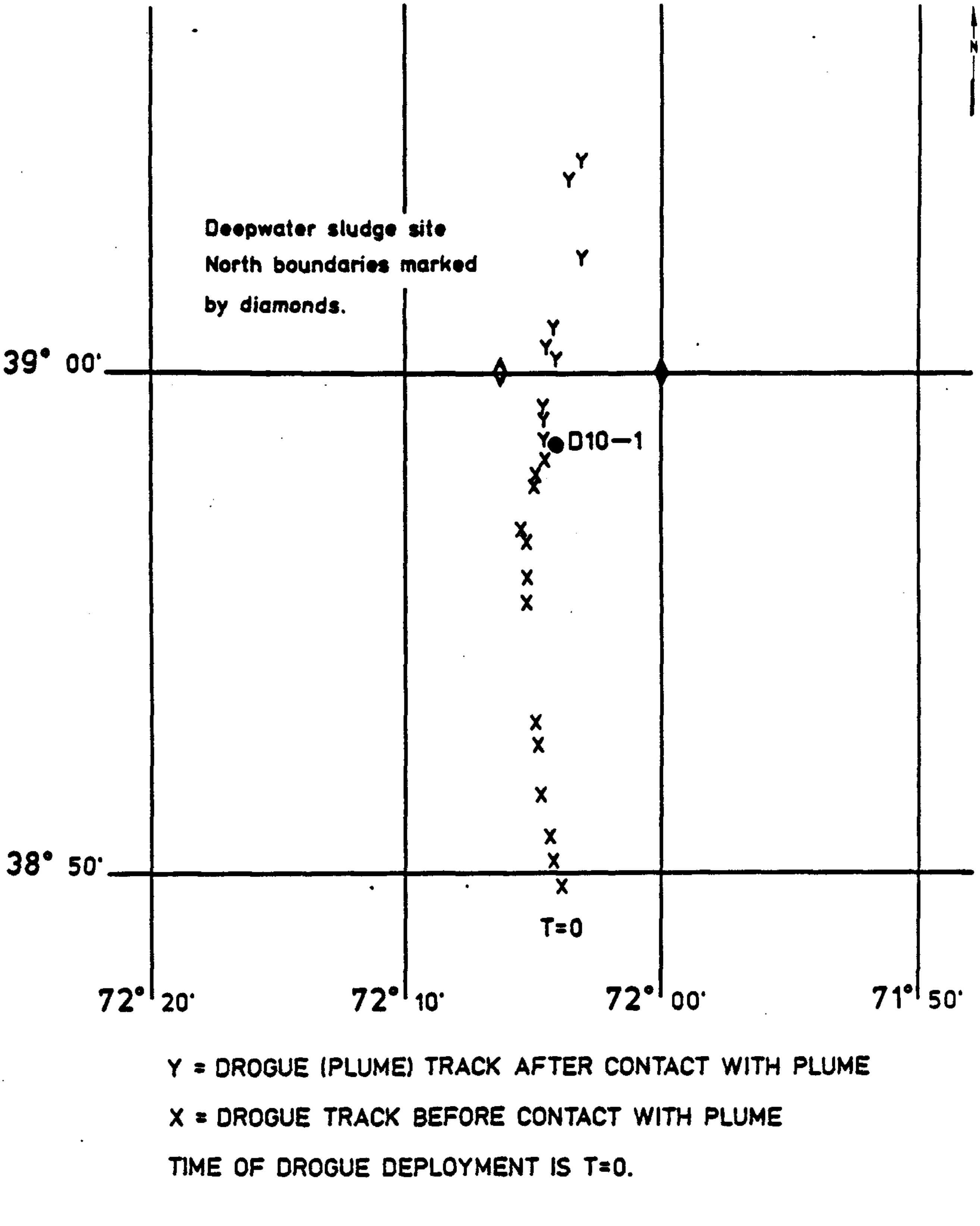


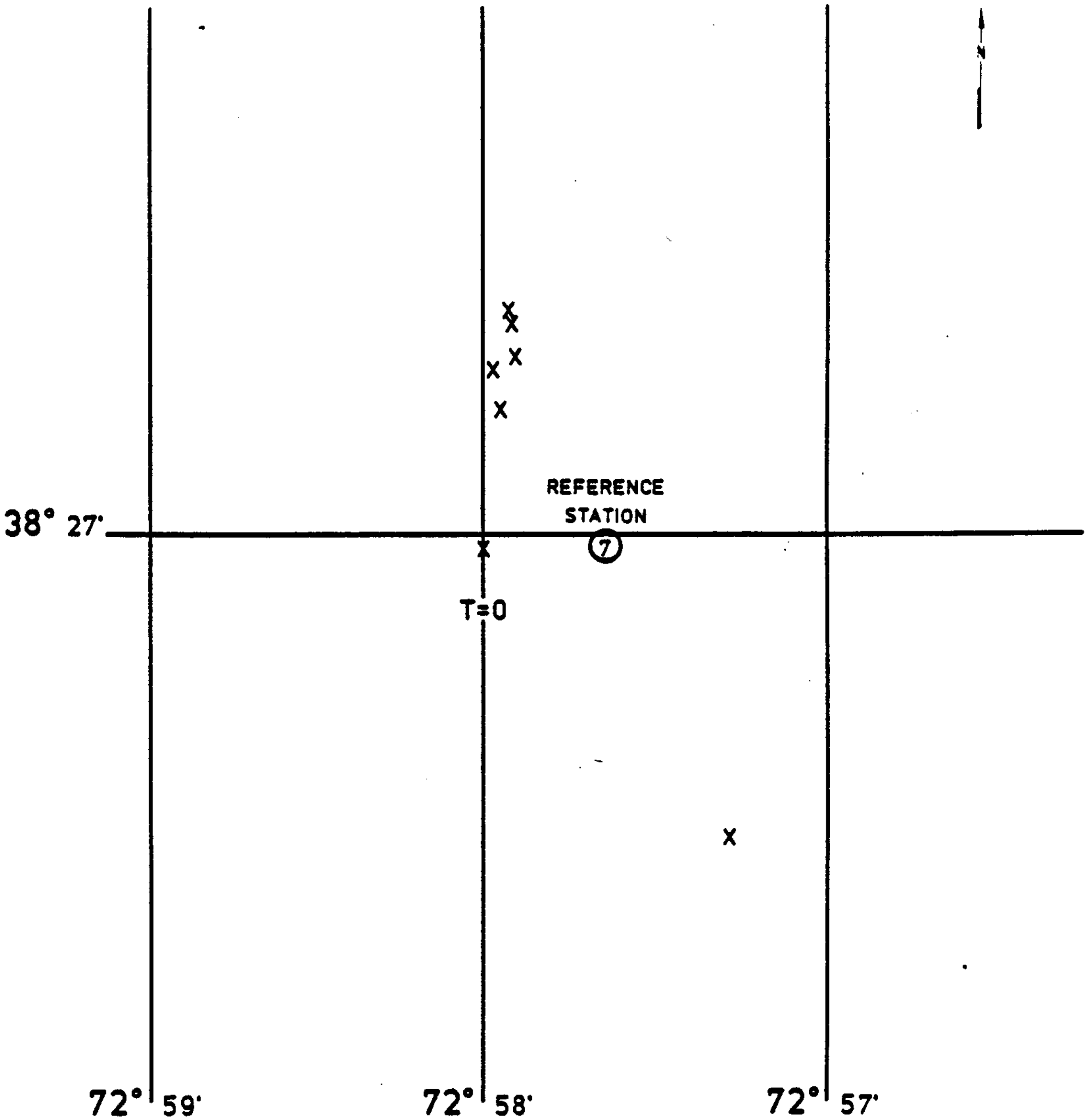
FIGURE 5. DROGUE DEPLOYMENT AND TRACKING BEFORE AND DURING THE SEWAGE SLUDGE DUMP

C. perfringens at Station D10-1 (the site of the dump). The results of the TSS analysis are presented in Table 12. Microbiology samples were analyzed for the presence and abundance of *C. perfringens*. These data are presented in Table 13, along with the sludge tracer data from the three DBR stations (discussed below). After sampling activities at the point of disposal were completed, DBR sampling was initiated. Results of TSS and *C. perfringens* analyses for Stations DBR-1, DBR-2, and DBR-3 are given in Tables 12 and 13, respectively.

5.3 REFERENCE STATIONS

5.3.1 Drogue Tracking at the Reference Stations

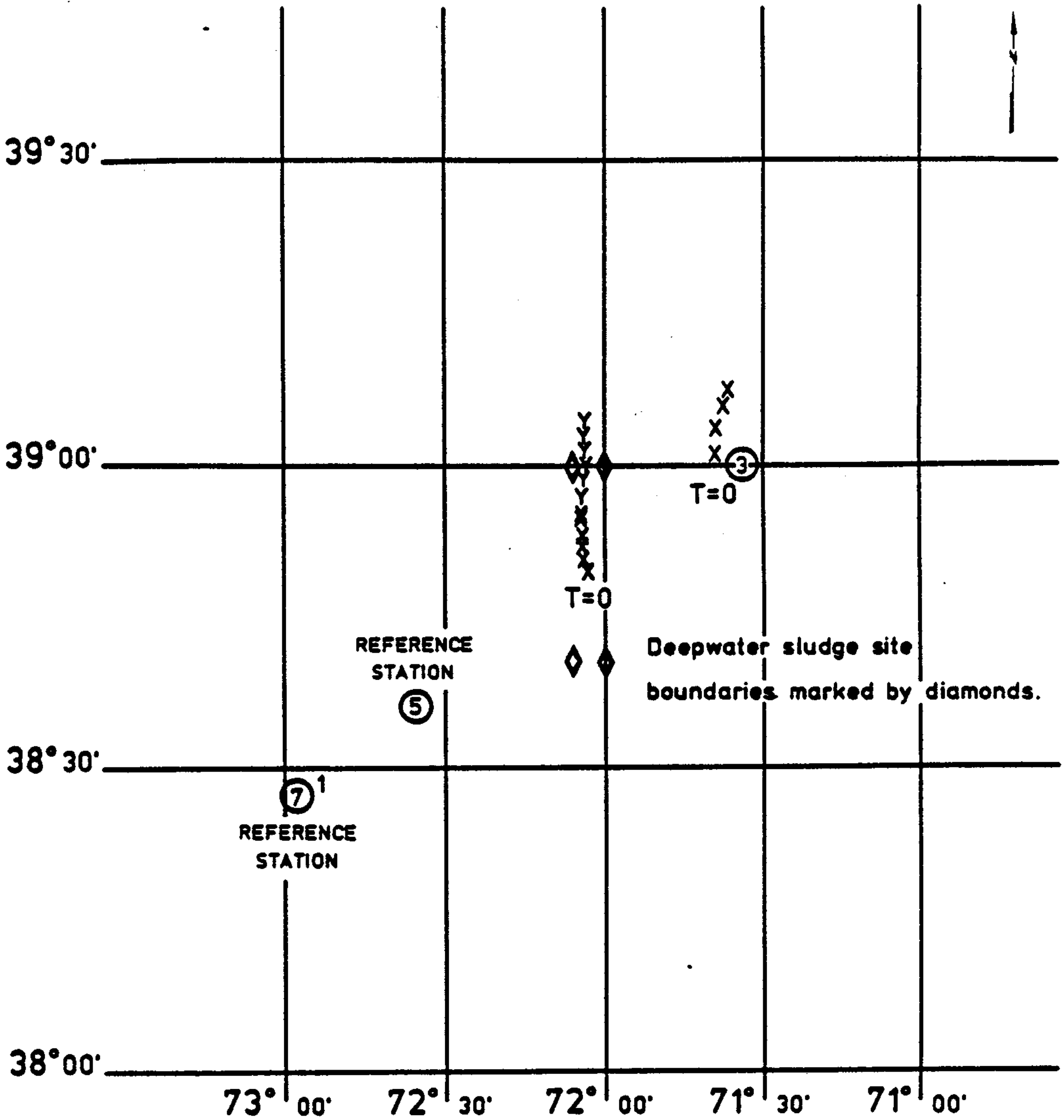
At Stations A-3 and A-7, a drogue, set to a depth of 10 m, was deployed and tracked for a short time. This activity was done to determine the direction of the surface currents at these stations and the extent of the influence of the ring (discussed in Section 5.1.1). The drogue tracks (marked by the "X"s) at Stations A-3 and A-7, presented in Figures 6 and 7, depict a northerly movement for each drogue relative to its respective point of release (T=0). Drift rates of the drogues were not determined during these activities. These data, coupled with the data from the DBR drogue tracking within the site, indicate the northerly flow of surface water in the vicinity of the dumpsite. This assessment is further supported by satellite imagery data that indicated the presence of the warm-core ring on the current movements at the site. Figure 8 presents a composite of all drogue tracking activities. The scale of the drogue-tracking composite (Figure 8) for Stations A-3, A-5, and A-7 covered a large area (in excess of 3600 nmi^2). The scale of Figure 7 for the drogue tracking activity at Station A-7 covered a considerably smaller area (approximately 4 nmi^2). As a result, the drogue track for Station A-7 was small with respect to those at Stations A-3 and A-5, and was not resolved in Figure 8.



X = DROGUE TRACK

TIME OF DROGUE DEPLOYMENT IS T=0.

FIGURE 7. EXPANDED DROGUE TRACK AT STATION A-7



Y = PLUME (DROGUE) TRACK AFTER DUMPING

X = DROGUE TRACK

TIME OF DROGUE DEPLOYMENT IS T=0.

1 SCALE NOT EXPANDED ENOUGH TO SHOW DROGUE TRACK IN THE VICINITY OF STATION A—7

FIGURE 8. DUMPSITE AND REFERENCE STATIONS SHOWING DROGUE TRACKS

5.3.2 Organic Constituents

5.3.2.1 SEAWATER

The particulate and dissolved fractions of three surface (10m) water samples and three subpycnocline (250 m) water samples collected from reference Stations A-3, A-5, and A-7 were analyzed for PAH, pesticide compounds, and coprostanol. The results of the PAH analysis for the dissolved sample fraction (filtrate) and the particulate fraction are shown in Tables 14 and 15, respectively. Results of PCB, pesticide, and coprostanol analysis for filtrate samples are shown in Table 16; the results of the particulate samples are presented in Table 17.

5.3.2.2 FILTER WIPES

Three wipe samples were taken from the deck of the ship in the vicinity of the extraction container (sample W-1), the top of the extraction container (sample W-2), and in the laboratory of the ship (sample W-3). These wipe samples were analyzed for PCB, PAH, pesticide compounds, and coprostanol. The data are reported in Tables 14 (PAH particulates), and 17 (PCB, pesticide, and coprostanol particulates).

5.3.3 Water Column Profiling - Expendable Bathythermograph (XBT)

Expendable bathythermograph (XBT) data (Figure 9) were collected at each station to determine the depth of the pycnocline. Based on XBT data, subpycnocline water sampling depths were determined for each station. At Station A-3, XBT data (Figure 9A) indicated the existence of three separate gradients at approximate depths of 50, 200, and 500 m, possibly confirming the presence a warm-core ring in the vicinity. Based on historical physical oceanographic data indicating the presence of a permanent pycnocline in the area, at approximately 200 m, provisions were made for pumping seawater for organic analyses from no deeper than 300 m. Consequently, all water column

TABLE 14. SUMMARY OF GC/MS SCAN ANALYSIS OF WATER SAMPLE FILTERS FOR POLYNUCLEAR AROMATIC HYDOCARBONS AND PHTHALATES IN ng/L

Analyte	Station A-3 300 m[b]	A-3 10 m[c]	A-7 250 m[b]	A-7 10 m[b]	A-5 250 m[b]	A-5 10 m[b]	Wipe Samples[a] W-1	W-2	W-3
Naphthalene	0.21 u[d]	0.20 u	0.21 u	0.21 u	0.21 u	0.21	1.0	0.21 u	0.21 u
C_1-N	0.25 u	0.24 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_2-N	0.17 u	0.16 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u
C_3-N	0.21 u	0.20 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u
C_4-N	0.21 u	0.20 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u
Acenaphthylene	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u
Biphenyl	0.22 u	0.21 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u
Acenaphthene	0.24 u	0.23 u	0.24 u	0.24 u	0.24 u	0.24 u	0.24 u	0.24 u	0.24 u
Fluorene	0.14 u	0.13 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u
C_1-F	0.18 u	0.17 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u
C_2-F	0.17 u	0.16 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u	0.17 u
C_3-F	0.14 u	0.13 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u
C_4-F	0.14 u	0.13 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u	0.14 u
Phenanthrene	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	1.0	0.16 u	0.16 u
Anthracene	0.29 u	0.24 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u
C_1-P	0.29 u	0.27 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u	0.29 u
C_1-Anthracene	0.25 u	0.24 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_2-P	0.18 u	0.17 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u
C_2-Anthracene	0.94 u	0.89 u	0.94 u	0.94 u	0.94 u	0.94 u	0.94 u	0.94 u	0.94 u
C_3-P	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u
C_4-P	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u	0.16 u
Dibenzothiophene	0.25 u	0.23 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_1-DBT	0.25 u	0.23 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_2-DBT	0.25 u	0.23 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_3-DBT	0.25 u	0.23 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
C_4-DBT	0.25 u	0.23 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Fluoranthene	0.21 u	0.20 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u	0.21 u
Pyrene	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u
Benz(a)anthracene	0.13 u	0.13 u	0.13 u	0.13 u	0.13 u	0.13 u	1.0	0.13 u	0.13 u
Chrysene	0.10 u	0.09 u	0.10 u	0.10 u	0.10 u	0.10 u	1.0	0.10 u	0.10 u
Triphenylene	0.10 u	0.09 u	0.10 u	0.10 u	0.10 u	0.10 u	0.10 u	0.10 u	0.10 u
Benzofluoranthene	0.18 u	0.17 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u	0.18 u
Benzo(e)pyrene	0.22 u	0.20 u	0.22 u	0.22 u	0.22 u	0.22 u	1.0	0.22 u	0.22 u
Benzo(a)pyrene	0.22 u	0.21 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u	0.22 u
Perylene	0.19 u	0.18 u	0.19 u	0.19 u	0.19 u	0.19 u	0.19 u	0.19 u	0.19 u
Bis(2-ethylhexyl)phthalate	0.19 u	0.18 u	0.19 u	0.19 u	0.19 u	0.19 u	1.0	0.19 u	0.19 u
Indeno(1,2,3-CD)pyrene	0.40 u	0.38 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u
Benzo(g,h,i)perylene	0.40 u	0.38 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u	0.40 u

[a]Assumed volume = 950L.
[b]Sample volume = 900 L.
[c]Sample volume = 950 L.
[d]u = Method detection limit.

TABLE 15. SUMMARY OF GC/MS SCAN ANALYSIS OF WATER SAMPLE FILTRATES FOR POLYNUCLEAR AROMATIC HYDROCARBONS AND PHTHALATES IN ng/L (INCLUDES WATER QUALITY CRITERIA)

Analyte	Station						Water* Quality Criteria (µg/L)
	A-3		A-7		A-5		
	300 m[a]	10 m[b]	250 m[a]	10 m[a]	250 m[a]	10 m[a]	
Naphthalene	1.0	2.0	1.0	1.0	4.0	2.0	7.5
C_1-N	3.0	2.0	3.0	3.0	8.0	5.0	
C_2-N	4.0	2.0	3.0	3.0	9.0	5.0	
C_3-N	2.0	1.0	1.0	1.0	5.0	2.0	
C_4-N	0.21 u[c]	0.20 u	0.42 u	0.42 u	1.0	0.42 u	
Acenaphthylene	0.16 u	0.16 u	0.33 u	0.33 u	0.33 u	0.33 u	
Biphenyl	0.22 u	0.21 u	0.45 u	0.45 u	1.0	0.45 u	
Acenaphthene	0.24 u	0.23 u	0.48 u	0.48 u	0.48 u	0.48 u	
Fluorene	0.14 u	0.13 u	0.27 u	0.27 u	0.27 u	0.27 u	
C_1-F	0.18 u	0.17 u	0.36 u	0.36 u	1.0	0.36 u	
C_2-F	0.17 u	0.16 u	0.35 u	0.35 u	0.35 u	0.35 u	
C_3-F	0.14 u	0.13 u	0.27 u	0.27 u	0.27 u	0.27 u	
C_4-F	0.14 u	0.13 u	0.27 u	0.27 u	0.27 u	0.27 u	
Phenanthrene	0.16 u	0.16 u	0.33 u	0.33 u	1.0	0.33 u	
Anthracene	0.29 u	0.24 u	0.57 u	0.57 u	0.57 u	0.57 u	
C_1-P	1.0	0.27 u	0.57 u	1.0	2.0	1.0	
C_1-Anthracene	0.25 u	0.24 u	0.50 u	0.50 u	0.50 u	0.50 u	
C_2-P	0.18 u	0.17 u	0.35 u	0.35 u	0.35 u	0.35 u	
C_2-Anthracene	0.94 u	0.89 u	1.87 u	1.87 u	1.87 u	1.87 u	
C_3-P	0.16 u	0.16 u	0.33 u	0.33 u	0.33 u	0.33 u	
C_4-P	0.16 u	0.16 u	0.33 u	0.33 u	0.33 u	0.33 u	
Dibenzothiophene	0.25 u	0.23 u	0.50 u	0.50 u	0.50 u	0.50 u	
C_1-DBT	0.25 u	0.23 u	0.50 u	0.50 u	0.50 u	0.50 u	
C_2-DBT	0.25 u	0.23 u	0.50 u	0.50 u	0.50 u	0.50 u	
C_3-DBT	0.25 u	0.23 u	0.50 u	0.50 u	0.50 u	0.50 u	
C_4-DBT	o.25 u	0.23 u	0.50 u	0.50 u	0.50 u	0.50 u	
Fluoranthene	0.21 u	0.20 u	0.42 u	0.42 u	0.42 u	0.42 u	16
Pyrene	0.18 u	0.18 u	0.37 u	0.37 u	0.37 u	0.37 u	
Benz(a)anthracene	0.13 u	0.13 u	0.27 u	0.27 u	0.27 u	0.27 u	
Chrysene	0.10 u	0.09 u	0.20 u	0.20 u	0.20 u	0.20 u	
Triphenylene	0.10 u	0.09 u	0.20 u	0.20 u	0.20 u	0.20 u	
Benzofluoranthene	0.18 u	0.17 u	0.36 u	0.36 u	0.36 u	0.36 u	
Benzo(e)pyrene	0.22 u	0.20 u	0.43 u	0.43 u	0.43 u	0.43 u	
Benzo(a)pyrene	0.22 u	0.21 u	0.44 u	0.44 u	0.44 u	0.44 u	
Perylene	0.19 u	0.18 u	0.39 u	0.39 u	0.39 u	0.39 u	
Bis(2-ethylhexyl)-phthalate	0.19 u	0.18 u	0.39 u	0.39 u	0.39 u	0.39 u	
Indeno(1,2,3-cd)-pyrene	0.40 u	0.38 u	0.80 u	0.80 u	0.80 u	0.80 u	
Benzo(g,h,i)-perylene	0.40 u	0.38 u	0.80 u	0.80 u	0.80 u	0.80 u	

[a]Sample volume = 900 L.
[b]Sample volume = 950 L.
[c]u = Method detection limit.
*U.S.EPA 1986.

TABLE 16. SUMMARY OF THE ANALYSIS OF WATER SAMPLE FILTRATES FOR PESTICIDES, PCBs, AND COPROSTANOL IN ng/L (INCLUDES WATER QUALITY CRITERIA)

Analyte	Station A-3 300 m[a]	Station A-3 10 m[b]	Station A-7 250 m[a]	Station A-7 10 m[a]	Station A-5 250 m[a]	Station A-5 10 m[a]	Water* Quality Criteria (µg/L)
Pesticides							
α-BHC[c]	0.170[d]	0.228[d]	0.017[d]	0.449[d]	0.057[d]	0.232[d]	340
β-BHC	0.021	0.00092 u[e]	0.00097 u	0.00097 u	0.00097 u	0.009	
γ-BHC[f]	0.030[d]	0.031[d]	0.015[d]	0.055[d]	0.030[d]	0.032	
δ-BHC	0.00148 u	0.00140 u	0.00148 u	0.00148 u	0.00148 u	0.010	
Heptachlor	0.019	0.00095 u	0.00100 u	0.00100 u	0.00100 u	0.00100 u	3.6
Aldrin[g]	0.00106 u	0.00100 u	0.00106 u	0.00106 u	0.00106 u	0.00106 u	1300
Heptachlorepoxide	0.00083 u	0.008[dh]	0.00683 u	0.018[d]	0.00083 u	0.010[d]	
α-Endosulfan	0.00105 u	0.00099 u	0.00105 u	0.00105 u	0.00105 u	0.00105 u	8.7
Dieldrin	0.017	0.023[i]	0.00101 u	0.00101 u	0.00101 u	0.00101 u	
4,4'-DDE	0.013	0.00114 u	0.00120 u	0.00120 u	0.00120 u	0.00120 u	
Endrin	0.021	0.031[j]	0.00280 u	0.00080 u	0.00280 u	0.00280 u	2.3
β-Endosulfan	0.00104 u	0.00098 u	0.00104 u	0.0104 u	0.00104 u	0.00104 u	
4,4'-DDD	0.008	0.00172 u	0.00181 u	0.00181 u	0.00181 u	0.010	
Endrin aldehyde	0.00217 u	0.00205 u	0.00217 u	0.00217 u	0.00217 u	0.00217 u	
Endosulfan sulfate	0.00199 u	0.00188 u	0.00199 u	0.00199 u	0.00199 u	0.00199 u	
4,4'-DDT	0.022	0.00097 u	0.00102 u	0.00102 u	0.00102 u	0.00102 u	1
Mirex	0.00118 u	0.00111 u	0.00118 u	0.00118 u	0.00118 u	0.00118 u	1
Methoxychlor	0.00160 u	0.00152 u	0.00160 u	0.00160 u	0.00160 u	0.00160 u	3
Chlordane	0.222 u	0.211 u	0.222 u	0.222 u	0.222 u	0.222 u	4
Toxaphene	0.444 u	0.421 u	0.444 u	0.444 u	0.444 u	0.444 u	0.2
Polychlorinated Biphenyls (PCBs)							
Aroclor 1242	0.178 u	0.168 u	0.178 u	0.178 u	0.178 u	0.178 u	30
Aroclor 1254	0.178 u	0.168 u	0.178 u	0.178 u	0.178 u	0.178 u	
Aroclor 1260	0.178 u	0.168 u	0.178 u	0.178 u	0.178 u	0.177 u	
Coprostanol[k]	0.000	0.000	0.000	0.000	0.000	0.000	

[a]Sample volume = 900 L.
[b]Sample volume = 950 L.
[c]Detection limit for 900-L samples for Stations A-3 (300 m), A-7 (250 and 10 m), A-5 (250 and 10 m) = 0.00090; for 950-L sample--Station A-3 (10 m) = 0.00095.
[d]Confirmed by second (DB-17) column.
[e]u = Method Detection Limit.
[f]Detection limit for 900-L samples for Stations A-3 (300 m), A-7 (250 and 10 m), A-5 (250 and 10 m) = 0.00126; for 950-L sample--Station A-3 (10 m) = 0.00095.
[g]Not confirmed by confirmatory analysis due to presence of contamination peak.
[h]Detection limit for 950-L sample--Station A-3 (10 m) = 0.00078.
[i]Detection limit for 950-L sample--Station A-3 (10 m) = 0.00095.
[j]Detection limit for 950-L sample--Station A-3 (10 m) = 0.00066.
[k]Concentration given in µg/L. Detection limit not determined.
* U.S.EPA 1986.

TABLE 17. SUMMARY OF THE ANALYSIS OF WATER SAMPLE FILTERS FOR PESTICIDES, PCBs, AND COPROSTANOL IN ng/L

Analyte	Station						Wipe Samples		
	A-3[a]		A-7		A-5				
	300 m[b]	10 m[c]	250 m[b]	10 m[b]	250 m[b]	10 m[b]	W10	W2	W3
Pesticides									
α-BHC	0.00022 u[d]	0.00021 u	0.00022 u	0.001[e]	0.001[e]	0.001[e]	0.00022 u	0.00022 u	0.00022 u
β-BHC	0.00024 u	0.00023 u	0.00024 u	0.002	0.00024 u	0.002	0.00024 u	0.00024 u	0.00024 u
γ-BHC	0.00031 u	0.00030 u	0.00031 u	0.00031 u	0.00031 u	0.00031 u	0.00031 u	0.00031 u	0.00031 u
δ-BHC	0.00037 u	0.00035 u	0.00037 u	0.00037 u	0.00037 u	0.00037 u	0.00037 u	0.00037 u	0.00037 u
Heptachlor	0.00025 u	0.005[f]	0.00025 u	0.00025 u	0.00025 u	0.004	0.002	0.001	0.003
Aldrin[g]	0.00026 u	0.00025 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u
Heptachlorepoxide	0.00021 u	0.00020 u	0.00021 u	0.00021 u	0.00021 u	0.00021 u	0.00021 u	0.00021 u	0.00021 u
α-Endosulfan	0.00026 u	0.00025 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u
Dieldrin	0.00025 u	0.00024 u	0.00025 u	0.00025 u	0.00025 u	0.00025 u	0.00026 u	0.00026 u	0.00026 u
4,4'-DDE	0.00030 u	0.00028 u	0.00030 u	0.00030 u	0.00030 u	0.00030 u	0.00025 u	0.00025 u	0.00025 u
Endrin	0.00070 u	0.00066 u	0.00070 u	0.00070 u	0.00070 u	0.00070 u	0.00030 u	0.00030 u	0.00030 u
β-Endosulfan	0.00026 u	0.00025 u	0.00026 u	0.00026 u	0.00026 u	0.00026 u	0.00070 u	0.00070 u	0.00070 u
4,4'-DDD	0.00045 u	0.00043 u	0.00045 u	0.00045 u	0.00045 u	0.00045 u	0.00026 u	0.00026 u	0.00026 u
Endrin aldehyde	0.00054 u	0.00051 u	0.00054 u	0.00054 u	0.00054 u	0.00054 u	0.00045 u	0.00045 u	0.00045 u
Endosulfan sulfate	0.00050 u	0.00047 u	0.00050 u	0.00050 u	0.00050 u	0.00050 u	0.00054 u	0.00054 u	0.00054 u
4,4'-DDT	0.00025 u	0.00024 u	0.00025 u	0.00025 u	0.00025 u	0.00025 u	0.00050 u	0.00050 u	0.00050 u
Mirex	0.00029 u	0.00028 u	0.00029 u	0.00029 u	0.00029 u	0.00029 u	0.00025 u	0.00025 u	0.00025 u
Methoxychlor	0.00040 u	0.00039 u	0.00040 u	0.00040 u	0.00040 u	0.00040 u	0.00029 u	0.00029 u	0.00029 u
Chlordane	0.05556 u	0.05263 u	0.05556 u	0.00056 u	0.00056 u	0.00056 u	0.00040 u	0.00040 u	0.00040 u
Toxaphene	0.11111 u	0.10526 u	0.11111 u	0.11111 u	0.11111 u	0.11111 u	0.00056 u	0.00056 u	0.00056 u
							0.11111 u	0.11111 u	0.11111 u
Polychlorinated Biphenyls (PCBs)									
Aroclor 1242	0.04444 u	0.04211 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u
Aroclor 1254	0.04444 u	0.04211 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u
Aroclor 1260	0.04444 u	0.04211 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u	0.04444 u
Coprostanol[h]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[a]Assumed volume = 950L
[b]Sample volume = 900 L.
[c]Sample volume = 950 L.
[d]u = Method Detection Limit.
[e]Confirmed by second column.
[f]Detection limit for 950-L sample--Station A-3 (10 m) = 0.00095.
[g]Not confirmed by confirmatory analysis due to presence of contamination peak.
[h]Concentrations given in μg/L. Detection limit not determined.

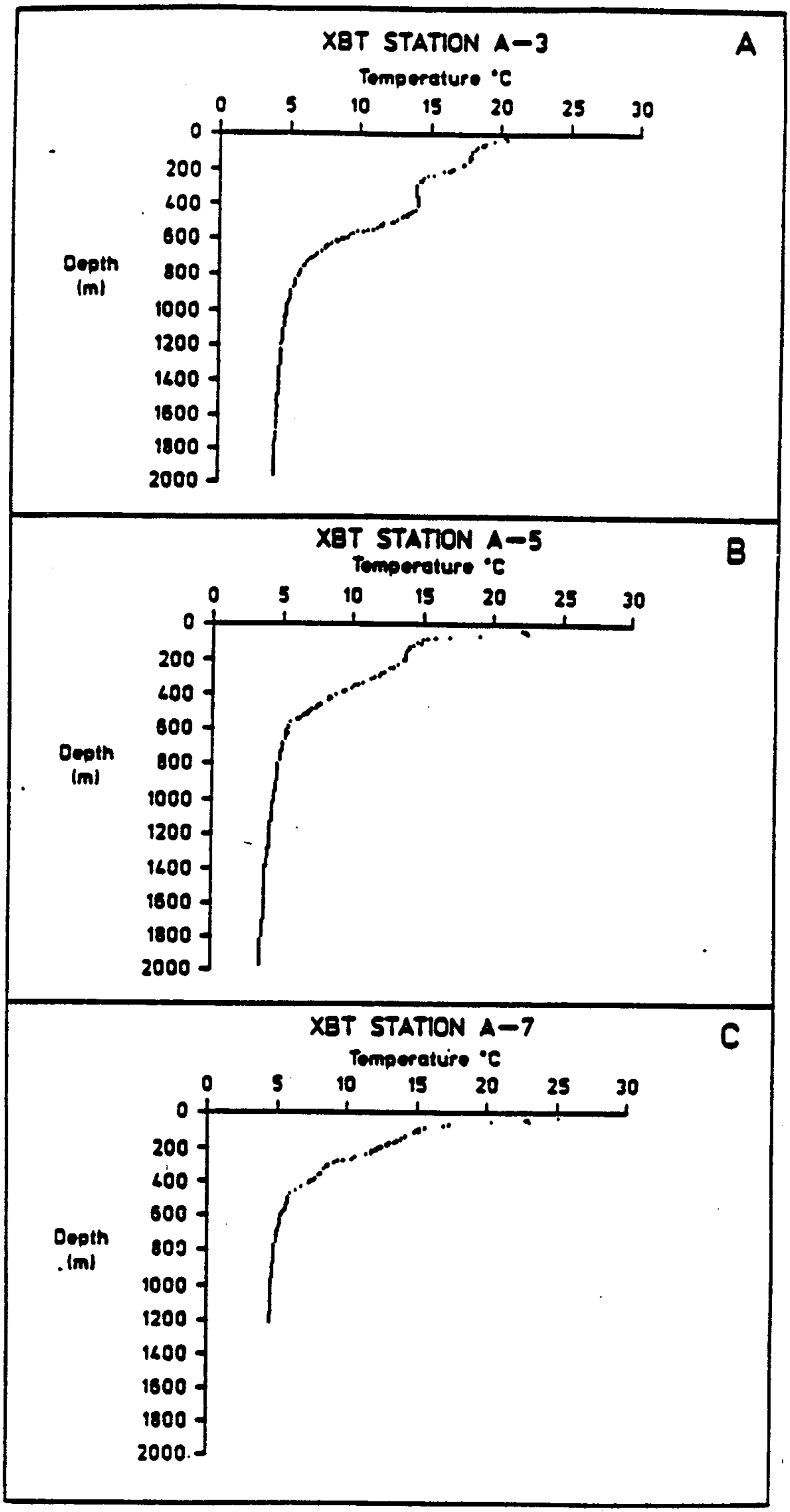


FIGURE 9. XBT TRACES FOR REFERENCE STATIONS A-3, A-5, AND A-7 FOR THE 1986 SUMMER SURVEY

samples were collected from a depth of 250 m. The XBT profiles for Stations A-5 and A-7 (Figures 9B and 9C) were typical of the 106-Mile Site and vicinity indicating a strong seasonal thermocline overlying a more gradual permanent pycnocline. At these stations, subpycnocline samples were pumped from a depth of 250 m.

5.3.4 Water Quality and Biochemical Parameters, and C. perfringens

Results of the water quality and biochemical measurements on surface (10m) and subpycnocline (250m) samples collected from reference Stations A-3, A-5, and A-7 are presented in Table 18. In addition, results from the shipboard analysis of *C. perfringens* are shown in Table 19.

5.3.5 Trace Metal

Trace metal samples, analyzed for Ag, Cd, Cr, Cu, Fe, Pb, and Zn, were collected in duplicate from subpycnocline water at Station A-5. Surface trace metal samples at Station A-5 were not collected because of unfavorable weather. Surface and subpycnocline samples were also collected in triplicate at Station A- 7. The results for each analyte are presented in Table 20.

5.4 CETACEAN, MARINE TURTLE, AND SEABIRD OBSERVATIONS (LEGS I AND II)

During each leg of the survey, the Manomet Bird Observatory provided an observer to collect data on the distribution and abundance of whales,birds, and marine turtles. These observations are discussed below. The full report is included as Appendix A.

During both legs of the survey, 13 species of seabirds were recorded along the shelf-break or in slope water within and near the 106-Mile Site. These species were combined into four species groups: petrels, shearwaters, skuas/Jaegers, and gulls. The mean density for the combined species groups is presented in Table 21. Shearwaters were the most abundant species group observed in the vicinity of the dumpsite with 1.346 birds/kn^2, although

TABLE 18. SUMMARY OF WATER QUALITY DATA FROM SEAWATER SAMPLES COLLECTED FROM REFERENCE STATIONS IN THE VICINITY OF THE 106-MILE SITE

Station	Replicate	Depth (m)	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)	Chlorophyll a (µg/L)	Phaeophytin (µg/L)	C/P Ratio	TSS (mg/L)	ATP (ng/L)
A3	1	10	16.4	36.40	6.75	7.95	2.9	0.003	0.006	0.50	0.516	110.013
	2	10	16.8	36.49	7.35	8.13	4.5	0.065	0.043	1.51	0.300	93.590
	3	10	17.5	36.48	7.25	8.19	2.5	0.004	0.008	0.50	1.180	72.741[a]
	$\bar{x}$[b]		16.9	36.46	7.12	8.09	3.3	0.024	0.019	0.84	0.665	92.115
	S.D.[c]		0.6	0.05	0.32	0.12	1.1	0.036	0.021	0.58	0.459	18.680
	1	250	16.1	36.41	6.65	7.95	5.2	0.002	0.008	0.25	0.212	7.062
	2	250	16.8	36.47	6.55	7.83	2.8	0.070	0.061	1.15	0.187	71.381
	3	250	17.5	36.37	6.60	8.08	1.9	0.187	0.064	2.92	0.100	6.720
	$\bar{x}$		16.8	36.42	6.60	7.95	3.3	0.086	0.044	1.44	0.166	28.388
	S.D.		0.7	0.05	0.05	0.13	1.7	0.094	0.032	1.36	0.059	37.234
A5	1	10	25.3	36.15	NA	8.31	4.0	0.093	0.027	3.44	0.320	30.864
	2	10	24.8	36.07	NA	8.31	4.0	0.093	0.027	3.44	1.23	11.317
	3	10	24.5	36.07	NA	8.31	4.4	0.087	0.032	2.72	0.92	13.857
	$\bar{x}$		24.9	36.10	NA	8.31	4.1	0.091	0.029	3.20	0.823	18.679
	S.D.		0.4	0.05	NA	0.00	0.2	0.003	0.003	0.42	0.463	10.628
	1	250	22.8	36.03	NA	8.14	2.2	0.006	0.025	0.24	0.700	2.709
	2	250	22.8	36.02	NA	8.12	2.0	0.000	0.020	0.00	0.488	0.977
	3	250	22.8	36.03	NA	8.12	2.1	0.000	0.020	0.00	0.638	0.219
	$\bar{x}$		22.8	36.03	NA	8.13	2.1	0.002	0.022	0.08	0.609	1.302
	S.D.		0.0	0.01	NA	0.01	0.1	0.003	0.003	0.14	0.109	1.276
A7	1	10	20.6	35.47	6.80	8.04	0.2	0.063	0.024	2.62	0.244	31.658
	2	10	18.3	35.74	7.13	8.18	0.3	0.096	0.043	2.23	0.164	83.009
	3	10	23.7	35.62	6.65	7.98	0.2	0.082	0.032	2.56	0.392	54.903
	$\bar{x}$		20.9	35.61	6.86	8.07	0.2	0.080	0.033	2.47	0.267	56.523
	S.D.		2.7	0.14	0.25	0.10	0.1	0.017	0.010	0.21	0.116	25.714
	1	250	15.4	35.83	4.65	7.86	0.3	0.003	0.017	0.18	0.362	12.320
	2	250	14.7	35.76	5.30	7.79	0.4	0.003	0.021	0.14	0.190	-0.034
	3	250	15.4	35.91	4.88	7.77	0.2	NA[d]	NA	NA	0.688	0.648
	$\bar{x}$		15.2	35.83	4.94	7.81	0.3	0.003	0.019	0.16	0.413	4.311
	S.D.		0.4	0.08	0.33	0.05	0.1	0.000	0.003	0.03	0.253	6.944

[a]Sample volume filtered = 3 L.
[b]$\bar{x}$ = Mean.
[c]S.D. = Standard Deviation.
[d]NA = Not analyzed.

TABLE 19. SUMMARY OF *C. perfringens* (COLONIES/100 mL) DATA FOR ALL REFERENCE STATIONS

Replicate	Volumes Filtered (liters)	A-3 10 m	A-3 250 m	A-7 10 m	A-7 250 m	A-5 10 m	A-5 250 m
1	0.1	0	0	0	0	0	0
	0.15[a]	0	-[b]	-	-	-	-
	0.5	0.4	0	0	0	0	0
	1.0	N	0	0	0	0	0
2	0.1	0	0	0	0	0	0
	0.35[a]	-	0	-	-	-	-
	0.5	0	0	0	0	0	0
	1.0	0.1	N	0	0	0	0
3	0.1	0	0	0	0	0	0
	0.5	0	0	0	0	0	0
	1.0	0	0	0	0	0	0

[a]Aliquot volume not originally planned, decided upon while on station.
[b]- Indicates sample collection not planned for that volume.
[c]N = Sample planned, but not collected.

TABLE 20. CONCENTRATION OF TRACE METALS IN µg/L IN WHOLE SEAWATER[a] (INCLUDES WATER QUALITY CRITERIA)

Station	Replicate	Depth (m)	Trace Metals Ag	Cd	Cr	Cu	Fe	Pb	Zn
A-5	R1	250	0.056 u[b]	0.036	0.25	0.29	0.79	0.029 u	0.65
A-5	R2	250	0.056 u	0.046	0.29	0.34	1.0	0.029 u	0.44
A-7	R1	10	0.056 u	0.026	0.24	0.21	0.49	0.029 u	0.44
A-7	R2	10	0.056 u	0.023	0.24	0.25	0.60	0.029 u	0.44
A-7	R3A	10	0.056 u	0.023	0.30	0.15	0.57	0.029 u	0.40
A-7	R3B	10	0.056 u	0.020	0.25	0.20	0.34	0.029 u	0.49
A-7	R1	250	0.056 u	0.057	0.23	0.20	1.7	0.029 u	0.56
A-7	R2	250	0.056 u	0.053	0.28	0.20	1.5	0.029 u	0.51
A-7	R3	250	0.056 u	0.051	0.25	0.30	2.0	0.029 u	0.55
Water Quality Criteria*			NA	9300	50[c]	2.9	NA	5.6	86
GO-FLO Blank (FMB)			0.072 u	0.003 u	0.10	0.14	2.1	0.38	1.3
Procedural Method Blank			0.002 u	0.003 u	0.16	0.12	0.47	0.015 u	0.67
Sample Detection Limit for Each Analyte			0.03 u	0.006 u	0.024 u	0.026 u	0.09 u	0.029 u	0.044 u

[a]Uncorrected Data (blank values not subtracted).
[b]u = Sample Detection Limit.
[c]Hexavalent Cr.
*U.S.EPA 1986/.

densities were generally very low for all seabird species. Audubon's shearwater, _Puffinus lherminieri_, was the most abundant shearwater species, with individual patch densities (within a 15 minute count) as high as 32.28 birds/km^2 (at 38°38'N latitude, 72°31'W longitude). Greater shearwaters (_P. gravis_), manx shearwater (_P. puffinus_), and Cory's shearwaters (_Calonectris diomedea_) were also observed.

Petrels and storm-petrels were the second most frequently observed species group (0.625 birds/km^2). Wilson's storm-petrel (_Oceanites oceanicus_), Leach's storm-petrel (_Oceanodroma leucorhoa_), and band-rumped storm-petrels (_O. castro_) were observed in flock densities ranging from 0.79 to 22.49 birds/kn^2. No cetaceans or marine turtles were observed at or in the vicinity of the 106-Mile Site on either of the two legs.

TABLE 21. DENSITIES (± S.D.) OF SEABIRDS BY SPECIES GROUPS OBSERVED WHILE IN SLOPE WATERS OR WITHIN THE 106-MILE SITE FROM THE OSV *Peter W. Anderson*, AUGUST 22 THROUGH 27 AND SEPTEMBER 15 THROUGH 20, 1986

Species Group	Density
Storm-Petrels	0.625 (2.433)
Wilson's storm-petrel, *Oceanites oceanicus*	
Leach's storm-petrel, *Oceanodroma leucorhoa*	
Band-rumped storm-petrel, *O. castro*	
Shearwaters	1.346 (5.054)
Greater shearwater, *Puffinus gravis*	
Manx shearwater, *P. puffinus*	
Audubon's shearwater, *P. lherminieri*	
Cory's shearwater, *Calonectris diomedea*	
Skuas/Jaegers	0.043 (0.227)
Pomarine jaeger, *Stercorarius pomarinus*	
Long-tailed jaeger, *S. longicaudus*	
Skua, *Skua* sp.	
Gulls	0.025 (0.194)
Hering gull, *Larus argentatus*	
Great black-backed gull, *L. marinus*	

6.0 DISCUSSION

This chapter is divided into three sections similar to the results chapter. The DBR section discusses the drogue/plume tracking and sludge tracer analyses. The reference station section discusses the results of the drogue tracking XBT organic constituents, water quality (including XBT), and trace metals. The last section discusses the endangered species data.

6.1 DBR STUDY

The DBR study provided preliminary nearfield data on the transport of sludge material to the dumpsite boundary. Some observations about the site include the following:

1. Based on drogue tracking data and satellite imagery during Leg I of the survey, currents in the mixed layer of the disposal site flowed north because of the presence of a warm-core eddy in the vicinity of the 106-Mile Site.

2. Visual observations of the plume boundaries and data from the analysis of sludge tracers, collected at all DBR stations, confirm that sludge was carried in detectable concentrations to and beyond the boundary of the dumpsite.

3. Sludge tracer data (Tables 12 and 13 for TSS and *C. perfringens* spores) appear to indicate temporal dispersion of the plume. As the elapsed time (ET) increased, the concentration of particulates (mg/L) from TSS samples appears to decrease with time. These data however are considerably variable and cannot be used to estimate dispersion and dilution rates.

Microbiological data indicate a similar trend. With time, *C. perfringens* colony counts dropped at all depths from values "too numerous to count" (TNTC) at D10-1 to countable numbers at Stations DBR-2 and DBR-3. A strong summer thermocline influenced by a warm-core eddy at 20 m was present at the DBR study area. It is probable that the thermocline was a barrier to settling sludge particles and that the sludge dumped from the preselected barge did not penetrate below 20 m. Because of these conditions, it is possible that TNTC values from depths of 30 and 75 m were caused by contamination of the sample bottle. All bottles were in the open configuration when they passed through the sludge plume.

This information is being used to design and implement an effective monitoring study for determining the dynamics of nearfield plume transport and for accurately quantifying the dispersion and dilution characteristics of sludge particles over time. An extensive plume tracking exercise was conducted in September 1987 and additional work is planned for Tier 2 (Nearfield Fate and Short-Term effects) of the monitoring plan.

6.2 REFERENCE STATION STUDY

6.2.1 Drogue Tracking

The results of the drogue tracking studies at reference stations A-3 and A-7 are presented in Figures 6 and 7. As indicated by the tracks at each stations the water mass traveled north and confirmed the presence of an eddy in the vicinity of the site.

This eddy information may be useful in developing a strategy for conducting monitoring surveys. Because the 106-Mile Site is a dynamic area with regard to influences by three different water masses (shelf water, Gulf Stream water, and slope water), it may be important to develop a monitoring strategy that will address influences from all major water masses. Continued monitoring will add considerably to our limited knowledge of surface currents near the 106-Mile Site and their impact on the transport of sludge in the nearfield and farfield.

6.2.2 XBT Traces

At Station A-3, the XBT traces (Figure 9) indicate that perhaps two water masses were strongly influencing the temperature profiles. It appears that the warm-core ring was disrupting the strong seasonal pycnocline normally apparent in the deep ocean during the late summer. The data presented in Figure 9 confirm satellite imagery information (Section 5.1), indicating that a warm-core eddy present at the 106-Mile Site. Stations A-5 (Figures 9B and 9C) and A-7 also appeared to be affected by the ring. The influences by the eddy at these stations were considerably less than at Station A-3.

6.2.3 Organic Constituents

The particulate and dissolved fractions from three surface waters (10 m) and three subpycnocline waters ($\geq$250 m) were collected from reference Stations A-3, A-5, and A-7 and analyzed for selected PAH, PCB, and pesticide compounds. The results of these analyses are strictly baseline data. Monitoring results obtained from future studies at the site may be compared to the data in this report to determine trends in the loading and dispersion of the reported compounds.

6.2.3.1 FILTRATE ANALYSIS

The results of the filtrate sample analyses for PAH are reported in Table 15. Almost all compounds were below the detection limit at all stations. However, naphthalene and alkylated (C_1-C_3) naphthalenes were found at all stations at both depths, at levels ranging from 1 to 9 ng/L. Station A-5 (250 m) showed the highest levels of total naphthalenes. At Stations A-3 and A-7, no trend between depth and/or station versus total naphthalenes was evident.

The only other PAH detected, C_1-phenanthrene, was found above the detection limit (1-2 ng/L) at the 300-m level of Station A-3, at the 10-m level of Station A-7, and at both the 10- and 300-m levels of Station A-5.

The results of pesticide and PCB analysis of the filtrate samples are presented in Table 16. No PCB (reported as aroclors) were found in any samples. In addition, no PCB isomers peaks were detected. Most pesticides (analyzed on a DB-5 capillary column and confirmed on a DB-17 capillary column) were below detection limits at all stations. Notable pesticides found above the detection limits at trace levels were α-BHC, β-BHC, γ-BHC, δ-BHC, 4,4'-DDE, 4,4'-DDT, and heptachlor. No coprostanol was detected in any water samples.

6.2.3.2 PARTICULATE ANALYSIS

The results from particulate material analysis for PAH are presented in Table 17. All PAH were below the detection limits in samples from all stations from surface and subpycnocline depths. The detection limits for particulate organic samples were lower than those for the dissolved fraction because the particulate fraction was more concentrated.

The results of the PCB, pesticides, and coprostanol analysis of particulate material samples are presented in Table 18. No PCBs (reported as aroclors) were found in any particulate or wipe samples. No coprostanol was determined in any particulate or wipe samples.

Only six occurrences of pesticides can be reported for any of the particulate material samples. Two occurrences of trace levels of α-BHC in the surface particulate (10 m) at Stations A-7 and A-5, and one of α-BHC in a subpycnocline particulate sample at Station A-5 were found. β-BHC was found in surface particulate samples from Stations A-5 and A-7. Finally, heptachlor was detected in surface particulate material from Station A-5.

6.2.3.3 FILTER WIPE ANALYSIS

Wipe samples from the surface of the ship were very clean, with only an occasional compound detected. The results of the analyses are based on an assumed filtration volume of 950L. Naphthalene, phenanthrene, chrysene, triphenylene, benzo(e)pyrene, and bis(2-ethylhexyl)phthalate were found in Sample W-1 at the 1 ng/L level. Samples W-2 and W-3 were free from any PAH contaminants.

Wipe samples from the surface of the sampling ship were free of pesticide and PCB contaminants, with the exception of trace levels of heptachlor. Heptachlor was found in all three wipe samples at an average level of 0.002 ng/L.

6.2.4 Water Quality and Biochemical Parameters

Examination of the water quality (Table 18) data for reference Stations A-3, A-5, and A-7 indicates that Stations A-3 and A-5 were possibly influenced by the warm-core ring. Discrete temperature values for surface and subpycnocline samples were not consistent with XBT data, possibly due to mishandling of the samples before analysis. Temperature profiles from the XBTs suggest that a warm-core ring was present at the site. Surface (XBT) temperatures did not indicate the presence of a ring. However, subpycnocline (XBT) temperatures from Stations A-3 and A-5 were considerably higher than the subpycnocline temperature at Station A-7 (9°C). These findings reinforce evidence that a ring was influencing the water mass near the site.

Surface salinity values at Stations A-3 and A-5 ranged from 36.10 parts per thousand (ppt) to 36.50 ppt. These values are indicative of the salinities found in the Gulf Stream. At Station A-7 surface salinities range from 35.47 to 35.74 which is indicative of open-ocean water. Many water quality values appear to be consistent with the data from the area (Battelle, 1987d,e). Surface pH values range from 7.98 at Station A-7 to 8.31 at Station A-5 and subpycnocline values range from 7.77 at Station A-7 to 8.14 at Station A-5. Dissolved oxygen values from surface and subpycnocline samples were consistent throughout the area. Surface TSS values ranged from 0.267 mg/L at Station A-7 to 0.82 mg/L at Station A-5. Subpycnocline values ranged from 0.166 mg/L at Station A-3 to 0.609 mg/L at Station A-5. These values are consistent with other TSS data from the 106-Mile Site (Battelle, 1987e).

The results of chlorophyll *a* (Table 18) analyses show considerable variation from station to station and from surface to subpycnocline depths. At Station A-3, chlorophyll values show the greatest inconsistency between surface and subpycnocline measurements. Surface values of 0.003 and 0.004 are more representative of subpycnocline values found at Stations A-5 and A-7 (Table 18) and Station A-5T (thermocline depth) (Battelle, 1987e). Conversely, subpycnocline values of 0.070 and 0.187 at Station A-3 are indicative of the surface measurements at Stations A-5 and A-7. It is possible that samples were mislabeled during shipboard processing and analysis.

Surface and subpycnocline data at Stations A-5 and A-7 are more consistent with baseline data from the area. However, surface values appear to be somewhat lower (up to an order of magnitude in some cases) than reported values (Battelle, 1987d,e) for the site and vicinity. Conversely, chlorophyll/phaeophytin (C/P) ratios from surface samples indicate chlorophyll concentrations above normal (normal C/P ratios = 1.4 to 1.7). Possible interference from another biological source (bacteria) that fluoresces in the frequency range of chlorophyll a could explain the discrepancy. These values may also be influenced by the ring activity in the area.

Surface ATP concentrations are considerably higher at Station A-3 (86.653 mg/L) than at Stations A-5 (18.68 mg/L) and A-7 (56.52 mg/L). Subpycnocline values range from 1.30 mg/L at Station A-5 to 28.37 mg/L at Station A-3. Higher ATP values at Station A-3 may be partially influenced by the presence of a warm-core ring.

Microbiological data (Table 19), from surface waters collected at the reference stations, indicate the presence of *C. perfringens* in background levels at Station A-3. This occurrence may have resulted from bottle contamination or ring activity in the area. Subpycnocline samples show no bacterial growth.

6.2.5 Trace Metals

Metal results from the August 1986 106-Mile Site survey vary. Silver and lead were not detected in any of the samples (detection limit 0.056 µg/L and 0.029 µg/L, respectively). All other metals measured were at detectable concentrations. Quality control samples indicate probable contamination of samples for chromium, copper and lead, iron, and zinc during processing. Procedural blanks contributed at least 50 percent of the reported values in Table 20, with the procedural blank for zinc being at least equal to the reported concentrations in the field samples. Furthermore, the blanks for the GO-FLO bottles also indicate potential significant contribution to the reported results. In spite of these difficulties, the replicability between field and procedural replicates is good. Recovery of field spikes appears to be low, probably reflecting the contamination during sampling or processing.

The reported concentrations for cadmium are higher than oceanographically accepted values for this area of the northwest, but they do indicate an increase with depth as is commonly found for this element. The concentrations of the other metals also are higher than accepted oceanographic concentrations for this region. The reported results for copper are consistent with previously reported values.

Even with potential contamination artifacts in the samples, all metal concentrations are less than EPA marine water quality criteria (Table 20). Because of the inability to accurately quantify the degree of sample contamination, it is impossible to compare this data with data from the literature or from the 106-Mile Site monitoring program to determine if there is a long-term change in the trace metal concentrations.

6.3 CETACEAN, MARINE TURTLE, AND SEABIRD OBSERVATIONS

No sightings of cetaceans and marine turtles were made during the survey. These data will be added to existing data to assess seasonal distributions and densities of marine mammals and turtles in areas of the 106-Mile Site.

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